EDITION 4

HESI ADMISSION ASSESSMENT

EXAM REVIEW

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Admission Assessment *Exam Review*

FOURTH EDITION

HESI

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Preface

Congratulations on purchasing the *HESI Admission Assessment Exam Review*! This study guide was developed based on the HESI Admission Assessment Exam; however, test items on the HESI Admission Assessment Exam are not specifically derived from this study guide. The content in this study guide provides an overview of the subjects tested on the Admission Assessment Exam and is designed to assist students in preparation for entrance into higher education in a variety of health-related professions. The *HESI Admission Assessment Exam Review* is written at the high school and beginning college levels and offers the basic knowledge that is necessary to be successful on the Admission Assessment Exam.

The HESI Admission Assessment exam consists of 10 different exams—8 academically oriented exams and 2 personally oriented exams. The academically oriented subjects consist of:

- Mathematics
- Reading Comprehension
- Vocabulary
- Grammar
- Biology
- Chemistry
- Anatomy and Physiology
- Physics

Chapter content in the *HESI Admission Assessment Exam Review* includes conversion tables and practice problems in the Mathematics chapter; step-by-step explanations in the Reading Comprehension and Grammar chapters; a substantial list of words used in health professions in the Vocabulary chapter; rationales and sample questions in the Biology and Chemistry chapters, helpful terminology in the Anatomy and Physiology chapter, and sample problems in the Physics chapter. Also included throughout the exam review are “HESI Hint” boxes, which are designed to offer students a suggestion, an example, or a reminder pertaining to a specific topic.

The personally oriented exams consist of a Learning Style assessment and a Personality Profile. These exams are intended to offer students insights into their study habits, learning preferences, and dispositions relating to academic achievement. Students generally like to take these personally oriented exams for the purpose of personal insight and discussion. Because each of these exams takes only approximately 15 minutes to complete, the school may include them in their administration of the Admission Assessment Exam.

Schools can choose to administer any one, or all, of these exams provided by the Admission Assessment. For example, programs that do not require biology,

chemistry, anatomy and physiology, or physics for entry would not administer those specific Admission Assessment science-oriented exams.

The HESI Admission Assessment Exam has been used by colleges, universities, and health-related institutions as part of the selection and placement process for applicants and newly admitted students for approximately 10 years.

Study Hints

It is always a good idea to prepare for any exam. When you begin to study for the Admission Assessment Exam, make sure you allocate adequate time and do not feel rushed. Set up a schedule that provides an hour or two each day to review material in the *HESI Admission Assessment Exam Review*. Mark the time you set aside on a calendar to remind yourself when to study each day. Before you begin, take the 25-question Pretest at the beginning of the text to help you initially assess your strengths and weaknesses of the content. For each section in the *HESI Admission Assessment Exam Review* review the material that is relevant to your particular field of the health care professions. Complete the review questions at the end of each chapter, then complete the 50-question Posttest at the end of the text. This Posttest gives you additional practice in the text's subject areas using a more comprehensive approach. The Posttest will help you to assess your readiness for the exam. Once you have completed your review and self-assessment of topics in the study guide, more test-taking practice is available on the text's corresponding Evolve site (http://www.elsevier.com/HESI/A2Review) with two comprehensive 82-question Practice Exams on the various subject areas that will help you prepare for the Admissions Assessment Exam. If you are having trouble with the review questions or the Practice Exams for a particular section, review that content in the *HESI Admission Assessment Exam Review* study guide again. It may also be helpful to go back to your textbook and class notes for additional review.

Test-Taking Hints

1. Read each question carefully and completely. Make sure you understand what the question is asking.
2. Identify the key words or phrases in the question. These words or phrases will provide critical information about how to answer the question.
3. Rephrase the question in your words.
   a. Ask yourself, "What is the question really asking?"
   b. Eliminate nonessential information from the question.
   c. Sometimes writers use terminology that may be unfamiliar to you. Do not be confused by a new writing style.
4. Rule out options (if they are presented).
   a. Read all of the responses completely.
   b. Rule out any options that are clearly incorrect.
   c. Mentally mark through incorrect options in your head.
   d. Differentiate between the remaining options, considering your knowledge of the subject.
5. Computer tests do not allow an option for skipping questions and returning to them later. Practice answering every question as it appears.

Do not second-guess yourself. TRUST YOUR ANSWERS.

Pretest

1. A die is rolled once. What is the probability of getting the number 5?
   A. $\frac{1}{6}$
   B. $\frac{2}{5}$
   C. $\frac{1}{5}$
   D. $\frac{5}{6}$
2. Select the meaning of the underlined word in the sentence.
   The veterinary technician gave the dog a <u>cursory</u> examination.
   A. Rigorous
   B. Thorough
   C. Concentrated
   D. Quick
3. In the hierarchic system of classification, which of the following is the least inclusive?
   A. Kingdom
   B. Class
   C. Genus
   D. Species
4. How does the trachea remain open like a hollow tube?
   A. Air pressure inside keeps it open.
   B. Supporting cartilaginous rings keep it open.
   C. It is reinforced with bone that cannot collapse.
   D. Special muscles are working to keep the trachea open.
5. Write the following quantity, 1 kilojoule (kj), in powers of tens:______
6. The quotient of y and -25 is -100; find the value of y.
   A. 4
   B. −2500
   C. −4
   D. 2500

   Use the passage below to answer questions 7-9.

Doppler Effect

Have you ever wondered why the whistle of a traveling, distant locomotive predicts its approach several yards before anyone actually sees it? Or why an oncoming ambulance's screaming siren is heard momentarily several feet before the ambulance comes into full view, before it passes you, and why its siren is still heard faintly well after the ambulance is out of sight?

What you are witnessing is a scientific phenomenon known as the *Doppler effect.* What takes place is truly remarkable. In both of these instances, when the train or ambulance moves toward the sound waves in front of it, the sound waves are pulled closer together and have a higher frequency. In either instance, the listener positioned in front of the moving object hears a higher pitch. The ambulance and locomotive are progressively moving away from the sound waves behind them, causing the waves to be farther apart and to have a lower frequency. These fast-approaching modes of transportation distance themselves past the listener, who hears a lower pitch.

7. What is the main idea of the passage?
   A. Trains and ambulances make distinctly loud noises.
   B. Low-frequency waves make high-pitched sounds.
   C. High-frequency waves make low-pitched sounds.
   D. The Doppler effect explains why sound is heard initially more strongly and then faintly after a moving object has passed.
8. What is the meaning of the word *phenomenon* in the second paragraph?
   A. Something that is lifeless to the senses
   B. Something that is nonchalant
   C. Something that is significant but unusual
   D. Something that is chemical in origin
9. Which sound waves have a lower pitch?
   A. Those waves that are closer together
   B. Those waves that are farther apart
   C. Those waves that travel a long distance
   D. Those waves that travel a short distance
10. What word meaning "abrupt, intense" best fits in the following sentence?
   The paramedics arrived at the home of a patient who was experiencing ________ chest pain.
   A. Distal
   B. Acute
   C. Chronic
   D. Dynamic
11. Which of the following sentences is grammatically incorrect?
   A. We took him to the store, the library, and the restaurant.
   B. We took him to the store and the library.
   C. We took him to the store, and then we went to the library.
   D. We took him to the store and then went to the library.

12. Sixteen (16) more than a number is nine (9). What is the number?
A. −7
B. 7
C. −25
D. 25
13. Select the best word for the blank in the following sentence.
I will ________ that chart to the patient's room later today.
A. Bring
B. Take
C. Brought
D. Took
14. The nucleus of an atom contains, or is made up of, which of the following?
A. Protons and electrons
B. Protons only
C. Protons and neutrons
D. Neutrons and electrons
15. After observing an event, you develop an explanation. This explanation is referred to as which of the following?
A. Hypothesis
B. Experiment
C. Conclusion
D. Theory
16. Which word in the following sentence should be replaced?
The department chairman stepped up to the podium.
A. Podium
B. Stepped
C. Chairman
D. Up
17. Which of the following is a benefit of the intermolecular hydrogen bonding of water? (Select all that apply.)
A. Water has a relatively high specific heat value.
B. Water has strong cohesive and adhesive properties.
C. Polarity of water allows it to act as a versatile solvent.
D. Water moves from higher to lower concentrations.
18. What is the best definition of the word *expedite*?
A. Impel
B. Empathize
C. Accelerate
D. Hinder
19. What is the charge on potassium in the compound KCl?
A. −1
B. +1
C. −2
D. +2
20. Which of the following are correct units for energy?
A. Joules

B. Kg-m/Sec^2
C. Newton
D. Watt

21. What mineral is responsible for muscle contractions?
A. Chloride
B. Sodium
C. Calcium
D. Magnesium

22. Of all the molecules that are significant to biology, which of the following are considered the most important?
A. Carbohydrates, lipids, protein, and nucleic acids
B. Carbohydrates, lipids, protein, and calcium
C. Carbohydrates, lipids, protein, and sulfur
D. Carbohydrates, lipids, protein, and iron

23. The reaction $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$ has a ratio of 2 parts ethane (C_2H_6) and 7 parts oxygen (O_2). How many parts of ethane (C_2H_6) will be needed to react with 21 parts of oxygen (O_2)?
A. 3 parts of ethane C_2H_6
B. 6 parts of ethane C_2H_6
C. 9 parts of ethane C_2H_6
D. 14 parts of ethane C_2H_6

24. A tissue examined under the microscope exhibits the following characteristics: cells found on internal surface of stomach, no extracellular matrix, cells tall and thin, no blood vessels in the tissue. What type of tissue is this?
A. Epithelial
B. Connective
C. Muscle
D. Cartilage
E. Nervous

25. Which of the following physical quantities are scalars? (Select all that apply.)
A. Energy
B. Time
C. Velocity
D. Distance

Answers to Pretest

1. A—There are 1 out of 6 chances on 1 die.
2. D
3. D
4. B
5. 10^3J
6. D—Multiply −25 × −100= 2500.
7. D
8. C
9. B
10. B
11. D—"We took him to the store" and "then we went to the library" are two independent clauses joined by the conjunction "and." Therefore, there should be a comma after the word "store." The correct sentence is "We took him to the store, and then we went to the library."
12. A—Add −16 to 9 in which the solution is −7.
13. B—In this sentence, the action is away from the speaker, who will carry the patient's chart from a near place (where the speaker is) to a far place (the patient's room). Therefore, the best word is "take."
14. C
15. A
16. C—The word "chairman" is considered sexist language. Sexist language can be avoided by changing *chairman* to *chair* or *chairperson.*
17. A, B, C
18. C
19. B
20. A
21. C
22. A
23. B
24. A
25. A, B, D

Mathematics

CHAPTER OUTLINE

KEY TERMS

Common Denominator
Constant
Denominator
Digit
Dividend
Divisor
Exponent
Expression
Factor
Fraction Bar

Improper Fraction
Least Common Denominator
Numerator
Percent
Place Value
Product
Proper Fraction
Proportion
Quotient
Ratio
Reciprocals
Remainder
Terminating Decimal
Variable

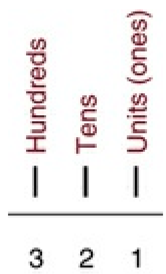
Members of the health professions use math every day to calculate medication dosages, radiation limits, nutritional needs, mental status, intravenous drip rates, intake and output, and a host of other requirements related to their clients. Safe and effective care is the goal of all who work in the health professions. Therefore, it is essential that students entering the health professions be able to understand and make calculations using whole numbers, fractions, decimals, and percentages.

The purpose of this chapter is to review the addition, subtraction, multiplication, and division of whole numbers, fractions, decimals, and percentages. Basic algebra skills will also be reviewed: evaluating expressions, and solving for a specific variable. Mastery of these basic mathematic functions is an integral step toward a career in the health professions.

Basic Addition and Subtraction

Vocabulary

Digit: Any number 1 through 9 and 0 (e.g., the number 7 is a digit).
Place Value: The value of the position of a digit in a number (e.g., in the number 321, the number 2 is in the "tens" position).



(From Ogden SJ, Fluharty LK: *Calculation of drug dosages: A work text,* ed 9, St. Louis, 2012, Elsevier/Mosby.)

> **HESI Hint**
>
> 1 ten = 10 ones
> 1 hundred = 100 ones
> 1 thousand = 1000 ones

Basic Addition

Example 1

$$462 + 133$$

$$\boxed{\begin{array}{r} 462 \\ +\ 133 \\ \hline 595 \end{array}}$$

Steps

1. Line up the **digits** according to **place value.**
2. Add the digits starting from right to left:
- Ones: 2 + 3 = 5
- Tens: 6 + 3 = 9
- Hundreds: 4 + 1 = 5

Addition with Regrouping

> **HESI Hint**
>
> To solve an addition problem, it may be necessary to regroup by moving, or carrying over, an extra digit from one place value column to the next.

Example 2

$$835 + 559$$

$$\boxed{\begin{array}{r} {}^{1} \\ 835 \\ +\ 559 \\ \hline 1{,}394 \end{array}}$$

Steps

1. Line up the digits according to place value.
2. Add:
- Ones: 5 + 9 = 14
- Carry the 1 to the tens place, which is one place to the left.
- Tens: 1 + 3 + 5 = 9
- Hundreds: 8 + 5 = 13

Basic Subtraction

Subtraction provides the difference between two numbers.

HESI Hint

It may be easier to solve a subtraction problem by first rewriting it vertically.

Example 1

$$5,234 - 4,112$$

$$\boxed{\begin{array}{r} 5,234 \\ -\ 4,112 \\ \hline 1,122 \end{array}}$$

Steps

1. Line up the digits according to place value.
2. Subtract:
- Ones: 4 − 2 = 2
- Tens: 3 − 1 = 2
- Hundreds: 2 − 1 = 1
- Thousands: 5 − 4 = 1

Subtraction with Regrouping

HESI Hint

Remember, if the number to subtract is not a positive number, you must borrow, or regroup, from one place value to a lower place value.

Example 2

$$457 - 29$$

$$\begin{array}{r} \scriptstyle 4\quad 17 \\ 4\,\cancel{5}\,\cancel{7} \\ -2\;9 \\ \hline 4\;2\;8 \end{array}$$

Steps

1. Align the digits according to place value.
2. Subtract:
3. 4 − 0 = 4

Sample Problems

Add or subtract each of the following problems as indicated.
1. 1,803 + 156 =
2. 835 + 145 =
3. 1,372 + 139 =
4. 123 + 54 + 23 =
5. 673 − 241 =
6. 547 − 88 =
7. 222 − 114 =
8. 12,478 − 467 =
9. Jeff walks 5 miles west then turns north and walks 8 miles. How far has Jeff walked?
10. Julie picks 26 tomatoes from the tomato plants in her garden. She gives 7 tomatoes to her next-door neighbor. How many tomatoes does Julie have left?

Basic Multiplication (Whole Numbers)

The process of multiplication is essentially repeated addition.

Vocabulary

Product: The answer to a multiplication problem.

HESI Hint

Remember, the zero is used as a placeholder to keep the problem aligned. If you do not skip a space, the answer will be incorrect. Below is an example of a well-aligned problem.

$$
\begin{array}{rl}
24571 & \\
\times \quad 1233 & \\
\hline
73{,}713 & \rightarrow \text{Ones} \\
737{,}130 & \rightarrow \text{Tens} \\
4{,}914{,}200 & \rightarrow \text{Hundreds} \\
+24{,}571{,}000 & \rightarrow \text{Thousands} \\
\hline
30{,}296{,}043 &
\end{array}
$$

Example 1

$$23 \times 5$$

$$\begin{array}{r} {}^{1} \\ 23 \\ \times\ 5 \\ \hline 115 \end{array}$$

Steps

1. Multiply one digit at a time.
2. Multiply 5 × 23.
- Ones: 5 × 3 = 15
  Carry the 1 to the tens place, and write the 5 in the ones place.
- Tens: 5 × 2 = 10 + 1 = 11

Example 2

$$623 \times 45$$

$$\begin{array}{r} 623 \\ \times\ 45 \\ \hline 3{,}115 \\ +24{,}920 \\ \hline 28{,}035 \end{array}$$

Zero (0) represents a placeholder for the ones place

Steps

1. Multiply 623 × 5.
- 5 × 3 = 15
- 5 × 2 = 10 + 1 (carried over) = 11
- 5 × 6 = 30 + 1 (carried over) = 31 (does not need to be carried)

2. Multiply 623 × 4 (remember to line up the ones digit with the 4 by using zero as a placeholder).
- 4 × 3 = 12
- 4 × 2 = 8 + 1 = 9
- 4 × 6 = 24

3. Add the two products together.
- 3,115 + 24,920 = 28,035 (the final **product**)

Example 3

$$301 \times 451$$

$$\begin{array}{r} 301 \\ \times\ 451 \\ \hline 301 \\ 15{,}050 \\ +\ 120{,}400 \\ \hline 135{,}751 \end{array}$$

Steps

1. Multiply 301 × 1.
- 1 × 1 = 1
- 1 × 0 = 0
- 1 × 3 = 3

2. Multiply 301 × 5.
- 5 × 1 = 5 (remember to use a zero for a placeholder)
- 5 × 0 = 0
- 5 × 3 = 15

3. Multiply 301 × 4.
- 4 × 1 = 4
- 4 × 0 = 0
- 4 × 3 = 12

4. Add the three products together.
- 301 + 15,050 + 120,400 = 135,751 (the final **product**)

Sample Problems

Multiply each of the following problems as indicated.

1. 846 × 7 =
2. 325 × 6 =
3. 653 × 12 =
4. 806 × 55 =
5. 795 × 14 =
6. 999 × 22 =
7. 582 × 325 =
8. 9438 × 165 =
9. Jan is preparing an examination for 29 students. Each student will have 30 questions, with no student having duplicate questions. How many questions will Jan need to prepare?
10. John is ordering lunch for the volunteers at the hospital. There are 12 units in the hospital, with 15 volunteers in each unit. How many lunches will John need to order?

Basic Division (Whole Numbers)

Vocabulary

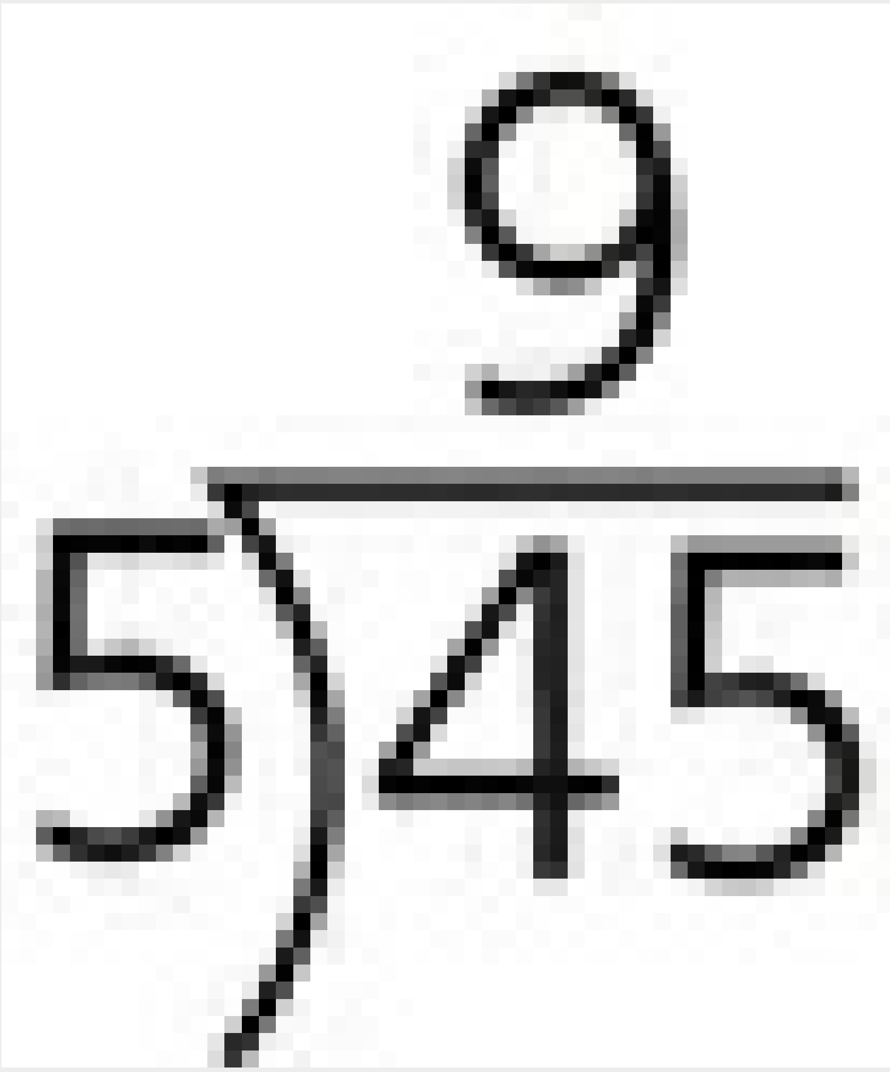
Dividend: The number being divided.

Divisor: The number by which the dividend is divided.

Quotient: The answer to a division problem.

Remainder: The portion of the dividend that is not evenly divisible by the divisor.

HESI Hint



The 45 represents the **dividend** (the number being divided), the 5 represents the **divisor** (the number by which the dividend is divided), and

the 9 represents the **quotient** (the answer to the division problem). It is best not to leave a division problem with a **remainder,** but to end it as a fraction or decimal instead. To make the problem into a decimal, add a decimal point and zeros at the end of the dividend and continue. If a remainder continues to occur, round to the hundredths place.

Example:

233.547 → 233.55 (the 7 rounds the 4 to a 5)

Example 1

$$40 \div 8$$

$$\boxed{\begin{array}{r} 5 \\ 8\overline{)\,40} \\ -40 \\ \hline 0 \end{array}}$$

Steps

1. Set up the problem.
2. Use a series of multiplication and subtraction problems to solve a division problem.
3. $8 \times ? = 40$

- Multiply: $8 \times 5 = 40$
- Subtract: $40 - 40 = 0$
- The quotient (or answer) is 5.

Example 2

$$672 \div 6$$

$$\begin{array}{r} 112 \\ 6\overline{)672} \\ \underline{-6}\downarrow\downarrow \\ 07\downarrow \\ \underline{-6}\downarrow \\ 12 \\ \underline{-12} \\ 0 \end{array}$$

Steps

1. Set up the problem.
2. Begin with the hundreds place.

- 6 × ? = 6. We know 6 × 1 = 6; therefore, place the 1 (quotient) above the 6 in the hundreds place (dividend). Place the other 6 under the hundreds place and subtract: 6 − 6 = 0.
- Bring down the next number, which is 7; 6 × ? = 7. There is no number that can be multiplied by 6 that will equal 7 exactly, so try to get as close as possible without going over 7. Use 6 × 1 = 6 and set it up just like the last subtraction problem: 7 − 6 = 1.
- Bring down the 2 from the dividend, which results in the number 12 (the 1 came from the remainder of 7 − 6 = 1).
- 6 × ? = 12; ? = 2. The two becomes the next number in the quotient. 12 − 12 = 0. There is not a remainder.
- The quotient (or answer) is 112.

Example 3

$$174 \div 5$$

$$
\begin{array}{r}
34.8 \\
5\overline{)174.0} \\
-\underline{15}\downarrow\downarrow \\
24\downarrow \\
-\underline{20}\downarrow \\
40 \\
-\underline{40} \\
0
\end{array}
$$

Steps

1. Set up the problem.
2. 5 does not divide into 1 but does divide into 17.
3. 5 × 3 = 15. Write the 3 in the quotient. (It is written above the 7 in 17 because that is the last digit in the number.)
- 5 × 3 = 15
- 17 − 15 = 2
4. Bring the 4 down. Combine the 2 (remainder from 17 − 15) and 4 to create 24.
5. Five does not divide evenly into 24; therefore, try to get close without going over.
- 5 × 4 = 20
- 24 − 20 = 4
6. There is a remainder of 4, but there is not a number left in the dividend. Add a decimal point and zeros and continue to divide.
7. The quotient (or answer) is 34.8 (thirty-four and eight tenths).

Sample Problems

Divide in each of the following problems as indicated.

1. 132 ÷ 11 =
2. 9,618 ÷ 3 =
3. 2,466 ÷ 2 =
4. 325 ÷ 13 =
5. 5,024 ÷ 8 =
6. 3,705 ÷ 5 =
7. 859 ÷ 4 =
8. 6,987 ÷ 7 =
9. There are 225 pieces of candy in a large jar. Ben wants to give the 25 campers in his group an even amount of candy. How many pieces of candy will each camper receive?
10. Edie has 132 tulip bulbs. She wants to plant all of the tulip bulbs in 12 rows. How many tulip bulbs will Edie plant in each row?

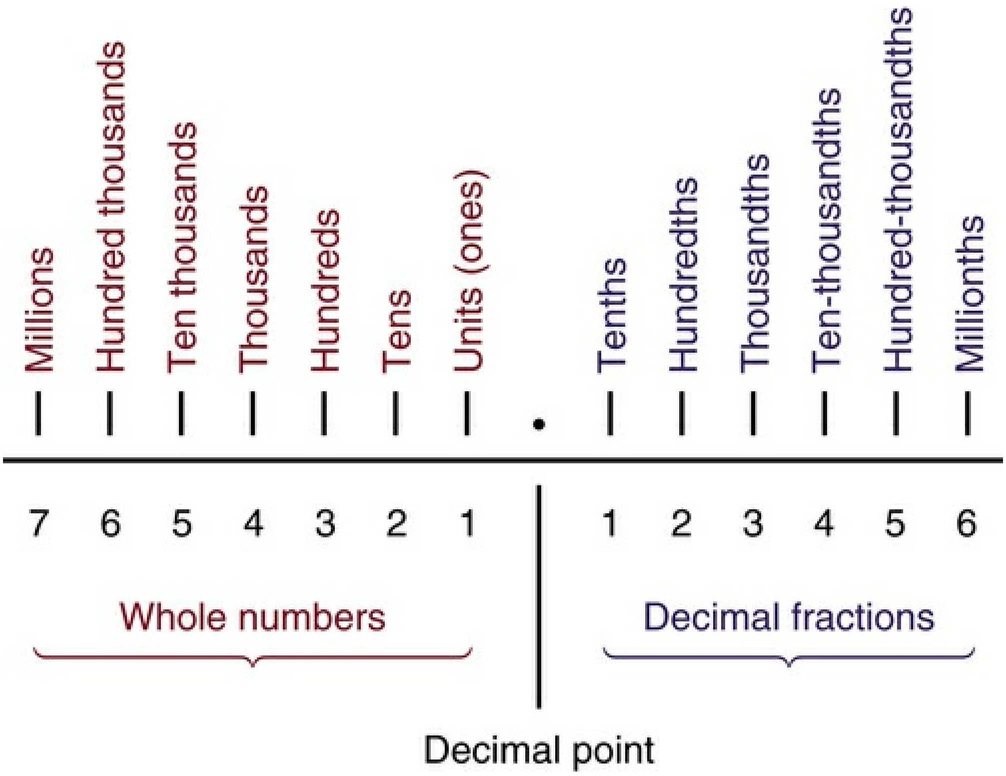
Decimals

A decimal pertains to tenths or to the number 10.

Vocabulary

Place value: Regarding decimals, numbers to the right of the decimal point have different terms from the whole numbers to the left of the decimal point. Each digit in a number occupies a position called a **place value.**

Addition and Subtraction of Decimals



(From Ogden SJ, Fluharty LK: *Calculation of drug dosages: A work text*, ed 10, St. Louis, 2016, Elsevier/Mosby.)

HESI Hint

Remember, whole numbers are written to the left of the decimal point and place values are written to the right of the decimal point. Line the numbers up vertically before solving the problem.

HESI Hint

The word "and" stands for the decimal when writing a number in words.
Example: 5.7 (five *and* seven tenths)

Example 1

$$2.6 + 3.1$$

$$\boxed{\begin{array}{r} 2.6 \\ +\ \ 3.1 \\ \hline 5.7 \end{array}}$$

Steps

1. Align the decimal points.
2. Add the tenths together: 6 + 1 = 7
3. Add the ones together: 3 + 2 = 5
4. Final answer: 5.7 (five and seven tenths).

Example 2

$$5 + 12.34$$

$$\boxed{\begin{array}{r} 12.34 \\ +\ \ 5.00 \\ \hline 17.34 \end{array}}$$

Steps

1. Align the decimal points.

- It might be difficult to align the 5 because it does not have a decimal point. Remember that after the ones place, there is a decimal point. To help with organization, add zeros (placeholders). **Example:** 5 = 5.00

2. Add the hundredths: 4 + 0 = 4
3. Add the tenths: 3 + 0 = 3
4. Add the ones: 2 + 5 = 7
5. Add the tens: 1 + 0 = 1
6. Final answer: 17.34 (seventeen and thirty-four hundredths).

Example 3

$$7.21 - 4.01$$

$$\boxed{\begin{array}{r} 7.21 \\ -\ 4.01 \\ \hline 3.20 \end{array}}$$

Steps

1. Align the decimal points.
2. Subtract the hundredths: 1 − 1 = 0
3. Subtract the tenths: 2 − 0 = 2
4. Subtract the ones: 7 − 4 = 3
5. Final answer: 3.20 (three and twenty hundredths).

Example 4

$$12 - 8.99$$

$$\begin{array}{r} {\scriptstyle 1\ \ 9\,10} \\ 1\cancel{2}.\cancel{0}\cancel{0} \\ -8.9\cancel{9} \\ \hline 3.01 \end{array}$$

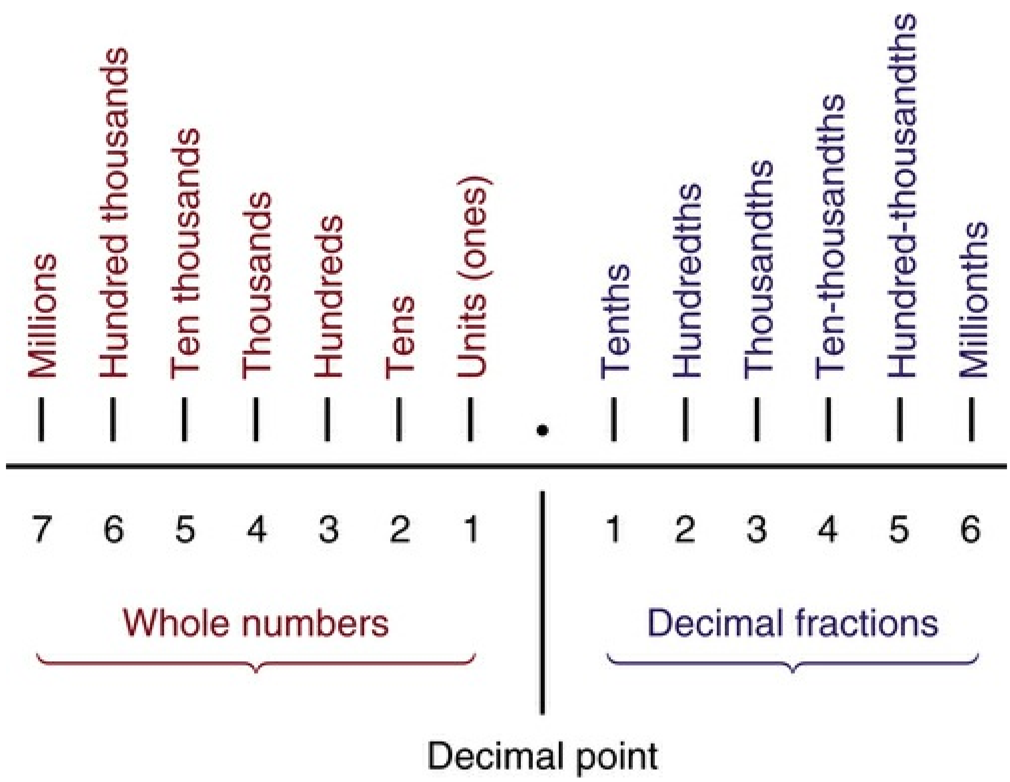
Steps

1. Align the decimal points.
2. Because 12 is a whole number, add a decimal point and zeros.
3. 0.00 − 0.99 cannot be subtracted; therefore, 1 must be borrowed from the 12 and regrouped.
4. The ones become 1, the tenths become 9, and the hundredths become 10.
5. Subtract the hundredths: 10 − 9 = 1
6. Subtract the tenths: 9 − 9 = 0
7. Subtract the ones: 11 − 8 = 3
- 1 was borrowed from the tens in order to subtract the 8.
8. Final answer: 3.01 (three and one hundredth).

Sample Problems

Solve each of the following decimal problems as indicated.
1. 9.2 + 7.55 =
2. 2.258 + 64.58 =
3. 892.2 + 56 =
4. 22 + 3.26 =
5. 8.5 + 7.55 + 14 =
6. 18 − 7.55 =
7. 31.84 − 2.430 =
8. 21.36 − 8.79 =
9. Bill has 2.5 vacation days left for the rest of the year and 1.25 sick days left. If Bill uses all of his sick days and his vacation days, how many days will he have off work?
10. Erin has 6.25 peach pies. She gives Rose 3.75 of the peach pies. How many pies does Erin have left?

Multiplication of Decimals



(From Ogden SJ, Fluharty LK: *Calculation of drug dosages: A work text*, ed 10, St. Louis, 2016, Elsevier/Mosby.)

Example 1

$$75.7 \times 2.1$$

$$\begin{array}{r} 75.7 \\ \times\ 2.1 \\ \hline 757 \\ +\ 15140 \\ \hline 158.97 \end{array}$$

1 decimal place
+ 1 decimal place
2 decimal places

Move the decimal point two places to the left in the final product.

Steps

1. Multiply 757 × 21 (do not worry about the decimal point until the final product has been calculated).
2. Starting from the right, count the decimal places in both numbers and add together (two decimal places).
3. Move to the left two places, and then place the decimal point.

Example 2

$$0.002 \times 3.4$$

$$\begin{array}{r} 0.002 \\ \times\quad 3.4 \\ \hline 0008 \\ +\ 00060 \\ \hline 0.0068 \end{array}$$

3 decimal places
+ 1 decimal place
4 decimal places

Move four places to the left.

Steps

1. Multiply 2 × 34.
2. Starting from the right, count the decimal places in both numbers and add together (four decimal places).
3. Move to the left four places, and then place the decimal.

Example 3

$$3.41 \times 7$$

$$\begin{array}{r} 3.41 \\ \times \quad 7 \\ \hline 23.87 \end{array}$$

$$\begin{array}{r} 2 \text{ decimal places} \\ + \ 0 \text{ decimal places} \\ \hline 2 \text{ decimal places} \end{array}$$

Move two places to the left.

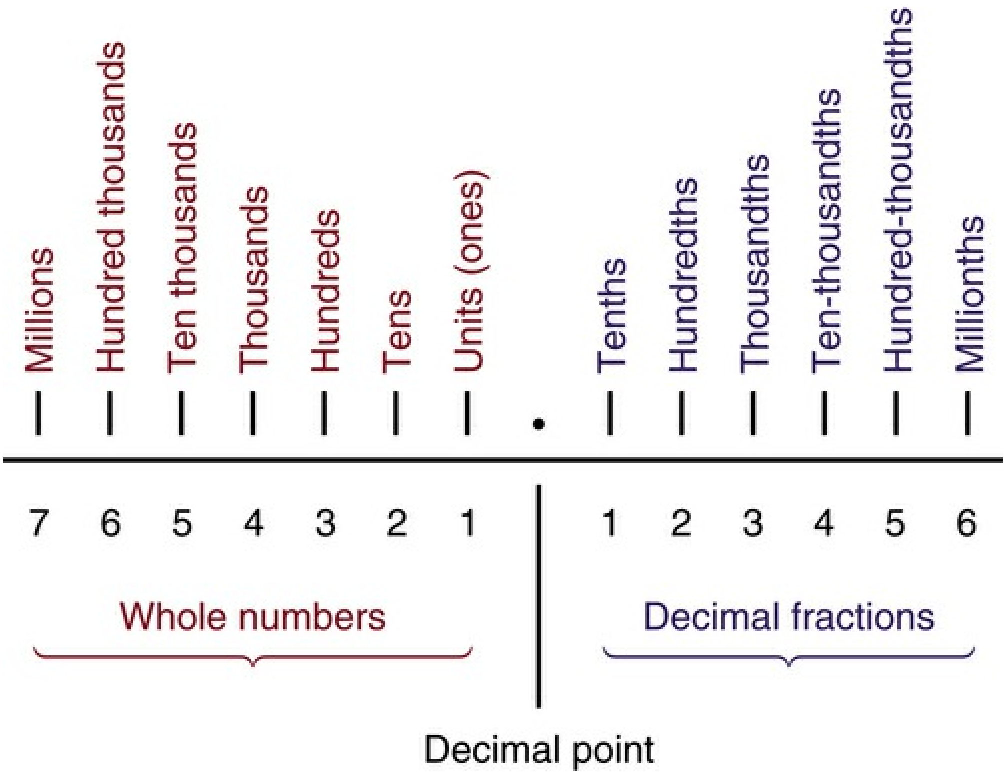
Steps

1. Multiply 341 × 7.
2. Starting from the right, count the decimal places in both numbers and add together (two decimal places).
3. Move to the left two places, and then place the decimal point.

Sample Problems

Multiply the decimals in the following problems as indicated.
1. 0.003 × 4.23 =
2. 98.26 × 8 =
3. 8.03 × 2.1 =
4. 250.1 × 25 =
5. 0.1364 × 2.11 =
6. 8.23 × 4 =
7. 0.058 × 64.2 =
8. 794.23 × .001 =
9. Jenny lost 3.2 lb each month for 6 months. How much weight has Jenny lost?
10. Richard wants to make 2.5 batches of sugar cookies. One batch calls for 1.75 cups of sugar. How many cups of sugar will Richard need for 2.5 batches of cookies?

Division of Decimals



(From Ogden SJ, Fluharty LK: *Calculation of drug dosages: A work text*, ed 10, St. Louis, 2016, Elsevier/Mosby.)

HESI Hint

The number 25 is a whole number. Though this number could be written 25.0, decimals are usually not displayed after a whole number.

Example 1

$$34 \div 2.5$$

$$\begin{array}{r}
13.6 \\
2.5\overline{)\,34.0.0} \\
-25\downarrow\downarrow \\
\hline
90\downarrow \\
-75\downarrow \\
\hline
150 \\
-150 \\
\hline
0
\end{array}$$

Steps

1. Set up the division problem.
2. Move the decimal point in 2.5 one place to the right, making it a whole number.
3. What is done to one side must be done to the other side. Move the decimal point one place to the right in 34, making it 340, and then bring the decimal point up into the quotient.
4. Divide normally.
- 25 × 1 = 25
- Subtract: 34 − 25 = 9
- Bring down the zero to make 90.
- 25 × 3 = 75. This is as close to 90 as possible without going over.
- Subtract: 90 − 75 = 15
- Add a zero to the dividend and bring it down to the 15, making it 150.
- 25 × 6 = 150
- 150 − 150 = 0

5. The quotient is 13.6.

Example 2

$$2.468 \div 0.2$$

$$
\begin{array}{r}
12.34 \\
0.\underline{2}\overline{)\;2.\underline{4}.68} \\
-\underline{2}\downarrow\downarrow\downarrow \\
04\downarrow\downarrow \\
-\underline{4}\downarrow\downarrow \\
06\downarrow \\
-\underline{6}\downarrow \\
08 \\
-\underline{8} \\
0
\end{array}
$$

Steps

1. Set up the division problem.
2. Move the decimal point in 0.2 over one place to the right, making it a whole number. 0.2 is now 2.
3. Move the same number of spaces in the dividend. 2.468 is now 24.68.
4. Bring the decimal point up to the quotient in the new position.
5. Divide normally.

Example 3

$$0.894 \div 0.05$$

$$
\begin{array}{r}
17.88 \\
0.\underline{05}\overline{)\;0.\underline{89}.40} \\
-\underline{5}\downarrow\downarrow\downarrow \\
39\downarrow\downarrow \\
-\underline{35}\downarrow\downarrow \\
44\downarrow \\
-\underline{40}\downarrow \\
40 \\
-\underline{40} \\
0
\end{array}
$$

Steps

1. Set up the division problem.
2. Move the decimal point in the divisor until it is a whole number. 0.05 is now 5.
3. Move the decimal point in the dividend the same number of spaces as was moved in the divisor. 0.894 is now 89.4.
4. Divide normally.

Sample Problems

Divide the decimals in the following problems as indicated.
1. $48 \div 0.4 =$
2. $144 \div 0.6 =$
3. $3.75 \div 0.4 =$
4. $56.2 \div 0.2 =$
5. $2.6336 \div 0.32 =$
6. $591 \div 0.3 =$
7. $0.72 \div 0.8 =$
8. $0.132 \div 0.11 =$
9. Stewart has 56 acres of land. He wants to divide the land into plots of 0.25 acres. How many plots of land will Stewart have after he divides the 56 acres?
10. Donna has 4.2 liters of fertilizer. If each pecan tree needs 0.7 liters of fertilizer and Donna uses all of the fertilizer, how many pecan trees does Donna have?

Fractions

In mathematics, a fraction is a way to express a part in relation to the total.

Vocabulary

Numerator: The top number in a fraction.

Denominator: The bottom number in a fraction.

Fraction Bar: The line between the numerator and denominator. The bar is another symbol for division.

Factor: A number that divides evenly into another number.

Least Common Denominator: The smallest multiple that two numbers share.

Improper Fraction: A fraction where the numerator is larger than the denominator.

Proper Fraction: A fraction where the denominator is larger than the numerator.

Common Denominator: Two or more fractions having the same denominator.

Reciprocals: Pairs of numbers that equal 1 when multiplied together.

Terminating Decimal: A decimal that is not continuous.

HESI Hint

- The **numerator** is the top number of the fraction. It represents the part or pieces.
- The **denominator** is the bottom number of the fraction. It represents the total or whole amount.
- The fraction bar is the line that separates the numerator and the denominator

$$\frac{\text{Numerator (part)}}{\text{Denominator (whole)}} \quad \text{Fraction bar}$$

Reducing Fractions Using the Greatest Common Factor

A **factor** is a number that divides evenly into another number.

Factors of 12:

- $1 \times 12 = 12$

• $2 \times 6 = 12$
• $3 \times 4 = 12$

12 {1, 2, 3, 4, 6, 12}: Listing the factors helps determine the greatest common factor between two or more numbers.

$$\frac{1}{2} = \frac{2}{4}, \frac{3}{6}, \frac{4}{8}, \frac{5}{10}, \frac{6}{12}, \frac{7}{14}, \frac{8}{16}, \frac{9}{18}, \frac{10}{20}$$

All represent one-half.

Reducing fractions can also be called reducing a fraction to its lowest terms or simplest form. A fraction is reduced to the lowest terms by finding an equivalent fraction in which the numerator and denominator are as small as possible. You may need to reduce fractions to work with them in an equation or for solving a problem. That means that there is no number, except 1, that can be divided evenly into both the numerator and the denominator.

$$1 = \frac{1}{1}, \frac{2}{2}, \frac{3}{3}, \frac{4}{4}, \frac{5}{5}, \frac{6}{6}, \frac{7}{7}, \frac{8}{8}, \frac{9}{9}, \frac{10}{10}$$

Example 1

$$\text{Reduce } \frac{7}{21}$$

Factors of 7 and 21:
7 {1, **7**}
21 {1, 3, **7**, 21}

The greatest common factor is 7; therefore, divide the numerator and denominator by 7.

$$\frac{7}{21} \div \frac{7}{7} = \frac{1}{3}$$

Example 2

$$\text{Reduce } \frac{12}{20}$$

Factors of 12 and 20:
12 {1, 2, 3, **4,** 6, 12}
20 {1, 2, **4,** 5, 10, 20}
The greatest common factor is 4 (they do have 1 and 2 in common, but the greatest factor is best).

$$\frac{12}{20} \div \frac{4}{4} = \frac{3}{5}$$

Least Common Denominator

The **least common denominator** (LCD) is the smallest multiple that two numbers share. Determining the LCD is an essential step in the addition, subtraction, and ordering of fractions.

Example 1

Find the LCD for $\frac{3}{4}$ and $\frac{7}{9}$.

Steps

1. List the multiples (multiplication tables) of each denominator.
- 4: 4 × 1 = 4, 4 × 2 = 8, 4 × 3 = 12, 4 × 4 = 16, 4 × 5 = 20, 4 × 6 = 24, 4 × 7 = 28, 4 × 8 = 32, 4 × 9 = 36, 4 × 10 = 40
- 4 {4, 8, 12, 16, 20, 24, 28, 32, 36, 40}—this will be the standard form throughout for listing multiples.
- 9 {9, 18, 27, 36, 45, 54, 63, 72, 81, 90}

2. Compare each for the least common multiple.
- 4 {4, 8, 12, 16, 20, 24, 28, 32, **36,** 40}
- 9 {9, 18, 27, **36,** 45, 54, 63, 72, 81, 90}

3. The LCD between 4 and 9 is 36 (4 × 9 = 36 and 9 × 4 = 36).

Example 2

Find the LCD for $\frac{3}{12}$ and $\frac{1}{8}$.

Steps

1. List the multiples of each denominator, and find the common multiples.
- 12 {12, **24,** 36, 48, 60, 72, 84, 96, 108, 120}
- 8 {8, 16, **24,** 32, 40, 48, 56, 64, 72, 80}

2. The LCD between 12 and 8 is 24 (12 × 2 = 24 and 8 × 3 = 24).

Changing Improper Fractions into Mixed Numbers

An **improper fraction** occurs when the numerator is larger than the denominator. An improper fraction should be reduced and made into a mixed number.

Example

$$\frac{17}{5} \rightarrow 5\overline{)17}^{\;3} \rightarrow 3\frac{2}{5}$$

$$\begin{array}{r} 3 \\ 5\overline{)17} \\ \underline{15} \\ 2 \end{array}$$

Steps

1. Turn an improper fraction into a mixed number through division. (The top number [numerator] goes in the box [17]; the bottom number [denominator] stays out [5].)
2. The 3 becomes the whole number.
3. The remainder (2) becomes the numerator.
4. The denominator stays the same.

Changing Mixed Numbers into Improper Fractions

A mixed number has a whole number and fraction combined.

Example

$$5\frac{2}{3} \rightarrow 5\frac{+2}{\times 3} = (5\times 3) + 2 = 17 \rightarrow \frac{17}{3}$$

Steps

1. To make a mixed number into an improper fraction, multiply the denominator (3) and whole number (5) together, then add the numerator (2).
2. Place this new numerator (17) over the denominator (3), which stays the same in the mixed number.

Addition of Fractions

Addition with Common Denominators

Example

$$\frac{3}{7}+\frac{2}{7}=\frac{5}{7}$$

Steps

1. Add the numerators together: 3 + 2 = 5.
2. The denominator (7) stays the same. This makes it a **common denominator.**
3. Answer: $\frac{5}{7}$ (five sevenths).

Addition with Unlike Denominators

Example

$$\frac{1}{5}+\frac{7}{10}$$

$$\frac{1\times 2}{5\times 2}=\frac{2}{10}$$

$$\frac{7\times 1}{10\times 1}=\frac{7}{10}$$

$$\frac{2}{10}+\frac{7}{10}=\frac{9}{10}$$

Steps

1. Find the LCD by listing the multiple of each denominator.
- 5 (5, **10**, 15, 20, 25, 30)
- 10 (**10**, 20, 30, 40, 50)
- The LCD is 10.

2. If the denominator is changed, the numerator must also be changed by the same number. Do this by multiplying the numerator and denominator by the

same number.

$$\frac{1 \times 2}{5 \times 2} = \frac{2}{10}$$

3. Because the denominator of the second fraction is 10, no change is necessary.
4. Add the numerators together, and keep the common denominator.
5. Reduce the fraction if necessary.

Addition of Mixed Numbers

Example

$$1\frac{1}{4} + 2\frac{8}{10}$$

$$1\frac{1}{4}\frac{\times}{\times}\frac{5}{5} = 1\frac{5}{20}$$

$$2\frac{8}{10}\frac{\times}{\times}\frac{2}{2} = 2\frac{16}{20}$$

$$1\frac{5}{20} + 2\frac{16}{20} = 3\frac{21}{20} = 4\frac{1}{20}$$

Steps

1. Find the least common denominator of 4 and 10 by listing the multiples of each.
- 4 (4, 8, 12, 16, **20**)
- 10 (10, **20,** 30)

2. Calculate the new numerator of each fraction to correspond to the changed denominator.
3. Add the whole numbers together, and then add the numerators together. Keep the common denominator 20.
4. The numerator is larger than the denominator (improper); change the answer to a mixed number (review vocabulary if necessary).

Sample Problems

Add the fractions in the following problems as indicated (remember to reduce the fraction as needed).

1. $\frac{1}{12}+\frac{5}{12}=$
2. $\frac{7}{21}+\frac{10}{21}=$
3. $\frac{1}{2}+\frac{4}{5}=$
4. $\frac{5}{7}+\frac{3}{14}=$
5. $\frac{4}{5}+\frac{6}{7}=$
6. $7\frac{1}{8}+2\frac{4}{12}=$
7. $5\frac{2}{9}+1\frac{2}{9}=$
8. $12\frac{1}{21}+3\frac{1}{3}=$
9. Mary is going to make a birthday cake. She will need 1⅔ cups of sugar for the cake and 2½ cups of sugar for the frosting. How many cups of sugar will Mary need to make and frost the birthday cake?
10. Greg is installing crown molding on two sides of a room. The length of one wall is 11¾ feet. The length of the other wall is 13⅞ feet. How much crown molding will Greg install in the room?

Subtraction of Fractions

Subtracting Fractions with Common Denominators

Example

$$\frac{7}{9}-\frac{4}{9}=\frac{3}{9}=\frac{1}{3}$$

Steps

1. Subtract the numerators: (7 − 4 = 3)
2. Keep the common denominator.
3. Reduce the fraction by dividing by the greatest common factor:

$$\frac{3}{9} \div \frac{3}{3} = \frac{1}{3}$$

Subtracting Fractions with Unlike Denominators

Example

$$\frac{5}{12} - \frac{1}{8} = ?$$

$$\frac{5 \times 2}{12 \times 2} = \frac{10}{24}$$

$$\frac{1 \times 3}{8 \times 3} = \frac{3}{24}$$

$$\frac{10}{24} - \frac{3}{24} = \frac{7}{24}$$

Steps

1. Find the LCD by listing the multiples of each denominator.
- 12 {12, **24**, 36, 48}
- 8 {8, 16, **24**, 32}
- The LCD is 24.

2. Change the numerator to reflect the new denominator. (What is done to the bottom must be done to the top of a fraction.)
3. Subtract the new numerators: 10 − 3 = 7. The denominator stays the same.

Borrowing from Whole Numbers

Example

$$5\frac{2}{3}-3\frac{4}{5}$$

$$5\frac{2\times5}{3\times5}=5\frac{10}{15}$$

$$^{4}\cancel{5}\frac{10}{15}+\frac{15}{15}=4\frac{25}{15}$$

$$3\frac{4\times3}{5\times3}=3\frac{12}{15}$$

$$4\frac{25}{15}-3\frac{12}{15}=1\frac{13}{15}$$

Steps

1. Find the LCD.
2. Twelve cannot be subtracted from 10; therefore, 1 must be borrowed from the whole number, making it 4, and the borrowed 1 must be added to the fraction.
3. Add the original numerator to the borrowed numerator: 10 + 15 = 25.
4. Now the whole number and the numerator can be subtracted.

HESI Hint

Fractions as a whole:

$$\frac{15}{15}=1\ \text{(one whole)}$$

Notice in the example under “Borrowing from Whole Numbers” that we added 15 to both the numerator and the denominator. We did this because it is one whole and it is the same denominator.

Sample Problems

Subtract the fractions in the following problems as indicated.

1. $\frac{3}{20} - \frac{2}{20} =$
2. $\frac{28}{37} - \frac{17}{37} =$
3. $\frac{17}{25} - \frac{3}{5} =$
4. $\frac{31}{54} - \frac{5}{9} =$
5. $1\frac{9}{10} - \frac{1}{5} =$
6. $15\frac{7}{18} - \frac{3}{9} =$
7. $25\frac{1}{7} - 12\frac{5}{7} =$
8. $30\frac{1}{2} - 13\frac{3}{4} =$
9. Alan is making a table. The table will be 6½ feet long and 4 feet wide. The board for the table is 7⅞ feet long and 4 feet wide. How much of the board will Alan need to cut off?
10. McKenna has 1⅔ cups of milk. She gives Mark ¾ cup of milk to make a cake. How much milk will McKenna have left?

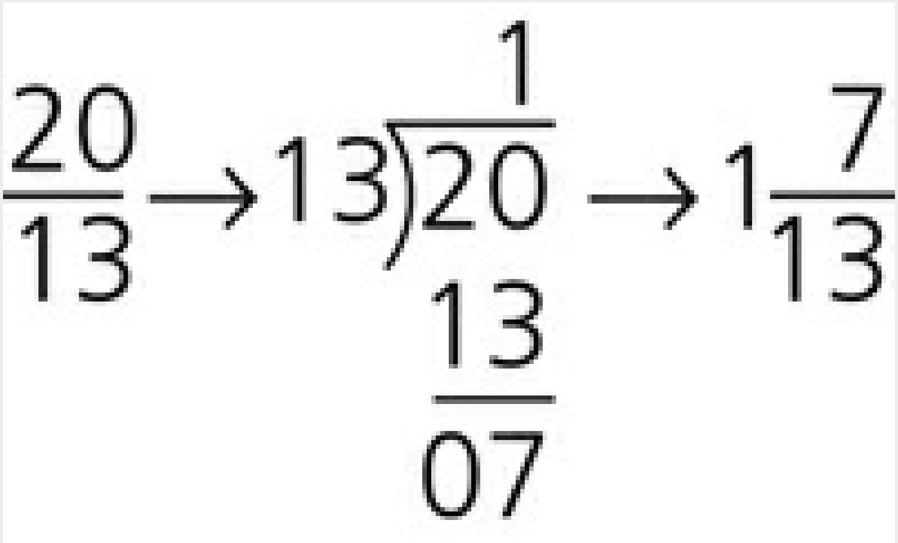
Multiplication of Fractions

HESI Hint

"Multiplying fractions is no problem. Top times top and bottom times bottom" (for example,

Top × Top and Bottom × Bottom.

To change an improper fraction into a mixed number, divide the numerator by the denominator.



The quotient becomes the whole number. The remainder becomes the numerator, and the denominator stays the same.

Example 1

$$\frac{4}{5} \times \frac{1}{2}$$

$$\frac{4}{5} \times \frac{1}{2} = \frac{4}{10} = \frac{2}{5}$$

Steps

1. Multiply the numerators together: $4 \times 1 = 4$.
2. Multiply the denominators together: $5 \times 2 = 10$.

3. Reduce the product by using the greatest common factor: $\frac{4}{10}\frac{\div 2}{\div 2}=\frac{2}{5}$.

Example 2

$$5\times\frac{4}{13}$$

$$\frac{5}{1}\times\frac{4}{13}=\frac{20}{13}=1\frac{7}{13}$$

Steps

1. Make the whole number 5 into a fraction by placing a 1 as the denominator.
2. Multiply the numerators: 5 × 4 = 20.
3. Multiply the denominators: 1 × 13 = 13.
4. Change the improper fraction into a mixed number.

Example 3

$$2\frac{1}{8}\times 7\frac{5}{6}$$

$$2\frac{1}{8}\times 7\frac{5}{6}$$

$$\frac{17}{8}\times\frac{47}{6}=\frac{799}{48}$$

$$\frac{799}{48}=16\frac{31}{48}$$

Steps

1. Change the mixed numbers into improper fractions.

$$2\frac{+1}{\times 8}=(2\times 8)+1=17\rightarrow\frac{17}{8}$$

$$7\frac{+5}{\times 6}=(7\times 6)+5=47\rightarrow\frac{47}{6}$$

2. Multiply the numerators and denominators together.

- 17 × 47 = 799 (numerator)
- 8 × 6 = 48 (denominator)
- Change the improper fraction into a mixed number.

$$\begin{array}{r} 16 \\ 48\overline{)799} \\ \underline{48} \\ 319 \\ \underline{288} \\ 31 \end{array} = 16\frac{31}{48}$$

Sample Problems

Multiply the following fractions and reduce the product to the lowest form and/or mixed fraction (also referred to as the common denominator).

1. $\frac{3}{5} \times \frac{2}{3} =$
2. $\frac{7}{9} \times \frac{1}{9} =$
3. $6 \times \frac{4}{5} =$
4. $1\frac{2}{5} \times 5 =$
5. $2\frac{1}{7} \times 1\frac{3}{4} =$
6. $4\frac{4}{5} \times 1\frac{4}{6} =$
7. $3\frac{1}{3} \times 2 =$
8. $1\frac{8}{12} \times 4\frac{1}{2} =$
9. Alec has six friends who each give him $2\frac{3}{4}$ pieces of gum. How many pieces of gum does Alec have now?
10. Rick rides $11\frac{1}{8}$ miles in an hour with his bike going uphill. If Rick rides downhill, he goes $2\frac{1}{2}$ times faster. How many miles will Rick go in an hour downhill?

Division of Fractions

HESI Hint

"Dividing fractions, don't ask why, inverse the second fraction and multiply."

Example:

$$\frac{1}{2} \div \frac{3}{8} \text{Inverse} \frac{3}{8} \to \frac{8}{3}$$

$$\text{Then multiply} \frac{1}{2} \times \frac{8}{3}$$
$$\frac{1}{2} \times \frac{8}{3} = \frac{8}{6}$$

Write as an improper fraction: $1\frac{2}{6}$ then reduce to lowest form: $1\frac{1}{3}$

$$\frac{3}{8} \to \frac{8}{3}\frac{3}{8} \times \frac{8}{3} = \frac{24}{24} = 1$$

These two numbers ($\frac{3}{8}$ and $\frac{8}{3}$) are **reciprocals** of each other because when they are multiplied together, they equal 1.

Example 1

$$\frac{1}{2} \div \frac{3}{8}$$

$$\frac{1}{2} \div \frac{3}{8}$$
$$\frac{1}{2} \times \frac{8}{3} = \frac{8}{6}$$

Steps

1. Inverse (or take the reciprocal) of the second fraction: $\frac{3}{8} \rightarrow \frac{8}{3}$.
2. Rewrite the new problem and multiply.
- 1 × 8 = 8 (numerator)
- 2 × 3 = 6 (denominator)

Example 2

$$1\frac{5}{6} \div \frac{3}{4}$$

$$1\frac{5}{6} \div \frac{3}{4}$$
$$\frac{11}{6} \div \frac{3}{4}$$
$$\frac{11}{6} \times \frac{4}{3} = \frac{44}{18}$$
$$2\frac{8}{18} = 2\frac{4}{9}$$

Steps

1. Change the mixed number into an improper fraction: $1\frac{5}{6} = (1 \times 6) + 5 = \frac{11}{6}$.
2. Rewrite the new problem with the improper fraction.
3. Inverse the second fraction.
4. Multiply the numerators and the denominators together.

$11 \times 4 = 44$ (numerators)
$6 \times 3 = 18$ (denominators)
5. Change the improper fraction into a mixed number. Reduce the mixed number.

Example 3

$$12 \div 2\frac{3}{8}$$

$$\frac{12}{1} \div \frac{19}{8}$$

$$\frac{12}{1} \times \frac{8}{19} = \frac{96}{19}$$

$$5\frac{1}{19}$$

Steps

1. Change the whole number into a fraction and the mixed number into an improper fraction.
2. Inverse the second fraction.
3. Multiply the numerators and then denominators together.
- $12 \times 8 = 96$
- $1 \times 19 = 19$
4. Change the improper fraction into a mixed number.

Sample Problems

Divide the fractions in the following problems and reduce to the lowest common denominator.

1. $\frac{4}{5} \div \frac{1}{7} =$
2. $\frac{12}{15} \div \frac{3}{5} =$
3. $\frac{7}{8} \div \frac{1}{6} =$
4. $1 \div \frac{1}{5} =$
5. $8 \div \frac{1}{4} =$
6. $2\frac{1}{4} \div \frac{1}{4} =$
7. $10 \div 3\frac{1}{3} =$
8. $12\frac{1}{3} \div 2 =$
9. Danny has $11\frac{1}{4}$ cups of chocolate syrup. He is going to make chocolate sundaes for his friends. Each sundae will have $\frac{3}{4}$ cup of chocolate. How many sundaes can Danny make?
10. Jenny has $8\frac{1}{3}$ yards of ribbon. She is making bows for her bridesmaids. Each bow has $\frac{5}{6}$ yard of ribbon. How many bridesmaids does Jenny have for her wedding?

Changing Fractions to Decimals

HESI Hint

"Top goes in the box, the bottom goes out."

This is a helpful saying in remembering that the numerator is the dividend and the denominator is the divisor.

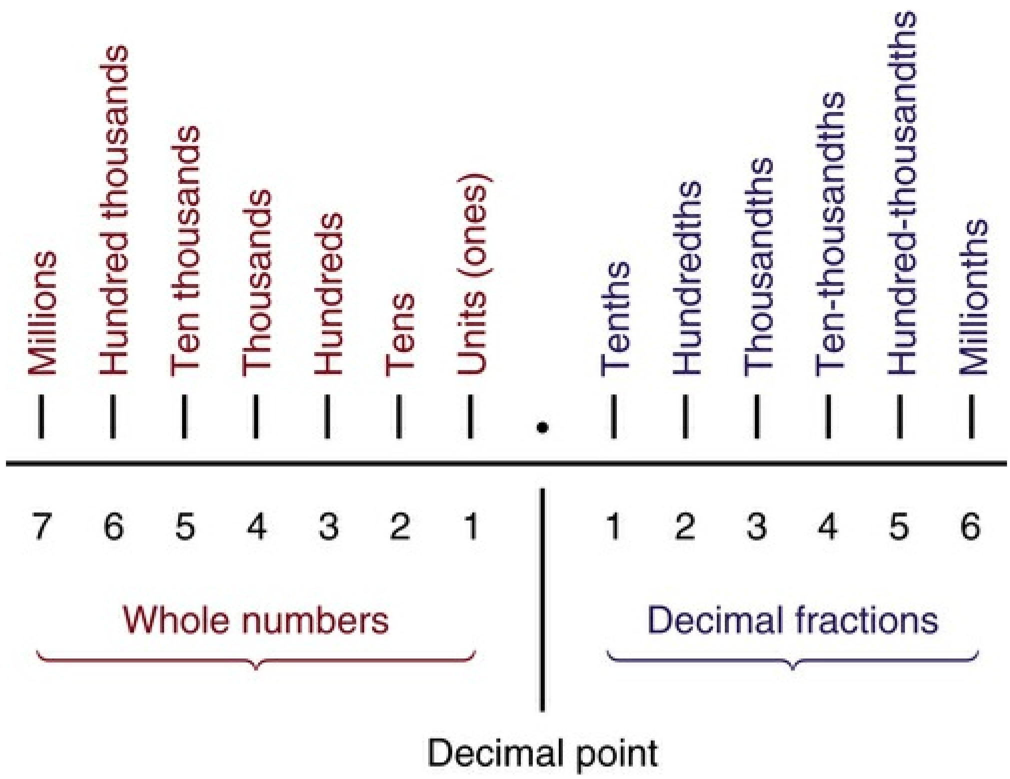
If the decimal does not terminate, continue to the thousandths place and then round to the hundredths place.

Example:

7.8666 → 7.87

If the number in the thousandths place is 5 or greater, round the number in the hundredths place to the next higher number.

However, if the number in the thousandths place is less than 5, do not round up the number in the hundredths place.



(From Ogden SJ, Fluharty LK: *Calculation of drug dosages: A work text*, ed 10, St. Louis, 2016, Elsevier/Mosby.)

Example 1

Change $\frac{3}{4}$ to a decimal.

$$\begin{array}{r} 0.75 \\ 4\overline{)3.00} \\ \underline{-28\downarrow} \\ 20 \\ \underline{-20} \\ 0 \end{array}$$

Steps

1. Change the fraction into a division problem.
2. Add a decimal point after the 3 and add two zeros.
- Remember to raise the decimal into the quotient area.
3. The answer is a **terminating decimal** (a decimal that is not continuous); therefore adding additional zeros is not necessary.

Example 2

Change $\frac{5}{8}$ to a decimal.

$$\begin{array}{r} 0.625 \\ 8\overline{)5.000} \\ \underline{-48\downarrow\downarrow} \\ 20\downarrow \\ \underline{-16\downarrow} \\ 40 \\ \underline{-40} \\ 0 \end{array}$$

Steps

1. Change the fraction into a division problem.

2. Add a decimal point after the 5 and add two zeros.
- Remember to raise the decimal into the quotient area.

3. If there is still a remainder, add another zero to the dividend and bring it down.
4. The decimal terminates at the thousandths place.

Example 3

Change $\frac{2}{3}$ to a decimal.

$$\begin{array}{r} 0.6666 \\ 3\overline{)2.0000} \\ -\underline{18}\downarrow\downarrow\downarrow \\ 20\downarrow\downarrow \\ -\underline{18}\downarrow\downarrow \\ 20\downarrow \\ -\underline{18}\downarrow \\ 20 \end{array}$$

Steps

1. Change the fraction into a division problem.
2. After the 2, add a decimal point and two zeros.
3. The decimal continues (does not terminate); therefore round to the hundredths place: 0.666 → 0.67. (It can also be written as $0.\overline{6}$. The line is placed over the number that repeats.)

Example 4

Change $2\frac{3}{5}$ to a decimal.

$$
\begin{array}{r}
0.60 \\
5\overline{)3.00} \\
-\underline{30}\downarrow \\
00 \\
-\underline{0} \\
0
\end{array}
$$

Steps

1. Change the fraction into a division problem.
2. After the 3, add a decimal and two zeros.
3. Place the whole number in front of the decimal: 2.6.

Sample Problems

Change the following fractions into decimals and round to the nearest thousandth.

1. $\frac{1}{5}$
2. $\frac{2}{5}$
3. $\frac{3}{8}$
4. $\frac{4}{5}$
5. $\frac{1}{3}$
6. $1\frac{1}{2}$
7. $\frac{3}{10}$
8. $2\frac{7}{8}$
9. $11\frac{11}{15}$
10. $\frac{11}{25}$

Changing Decimals to Fractions

Example 1

Change 0.9 to a fraction.

$$\boxed{0.9 \rightarrow \frac{9}{10}}$$

Steps

Knowing place values makes it very simple to change decimals to fractions.
1. The last digit is located in the tenths place; therefore, the 9 becomes the numerator.
2. 10 becomes the denominator.

Example 2

Change 0.02 to a fraction.

$$\boxed{0.02 \rightarrow \frac{2}{100} = \frac{1}{50}}$$

Steps

1. The 2 is located in the hundredths place.
2. The numerator becomes 2, and 100 becomes the denominator.
3. Reduce the fraction.

Example 3

Change 0.25 to a fraction.

$$\boxed{0.25 \rightarrow \frac{25}{100} = \frac{1}{4}}$$

Steps

1. Always look at the last digit in the decimal. In this example the 5 is located in the hundredths place.
2. The numerator becomes 25, and 100 becomes the denominator.
3. Reduce the fraction.

Example 4

Change 3.055 into a fraction.

$$\boxed{3.055 \rightarrow 3\frac{55}{1000} \rightarrow 3\frac{11}{200}}$$

Steps

1. The 5 is located in the thousandths place.
2. The numerator becomes 55, and 1,000 becomes the denominator. The 3 is still the whole number.
3. Reduce the fraction.

Sample Problems

Change the following decimals into fractions and reduce to the lowest form.

1. 0.08 =
2. 0.025 =
3. 0.125 =
4. 0.17 =
5. 0.3 =
6. 2.75 =
7. 7.07 =
8. 12.0001 =
9. 3.48 =
10. 0.275 =

Ratios and Proportions

Vocabulary

Ratio: A relationship between two numbers.
Proportion: Two ratios that have equal values.

HESI Hint

Ratios can be written several ways.

As a fraction: $\frac{5}{12}$
Using a colon: 5:12
In words: 5 to 12
Proportions can be written two ways.

$$\frac{5}{12} = \frac{25}{60}$$
$$5:12::25:60$$

NOTE: The numerator is listed first, then the denominator (known as the foil method).

Example 1

Change the decimal to a ratio.

$$0.025 \rightarrow \frac{25}{1000} \rightarrow \frac{1}{40} \rightarrow 1:40$$

Steps

1. Change the decimal to a fraction.
2. Reduce the fraction.
3. The numerator (1) is the first listed number.
4. Then write the colon.
5. Finally, place the denominator (40) after the colon.

Example 2

Change the fraction to a ratio.

$$\frac{5}{6} = 5:6$$

Steps

1. The numerator (5) is the first listed number.
2. Then write the colon.
3. Finally, place the denominator (6) after the colon.

Example 3

Solve the proportion (find the value of *x*).

$$7:10::14:x$$

$$7:10::14:x$$

$$\frac{7}{10} = \frac{14}{x}$$

$$\frac{7}{10} \overset{\times 2}{\underset{\times 2}{=}} \frac{14}{x}$$

$$\frac{7}{10} = \frac{14}{x}$$

$$x = 20$$

Steps

1. Rewrite the proportion as a fraction (this might help to see the solution).
2. Note that 7 × 2 = 14; therefore, 10 × 2 = 20.
- Multiply 14 × 10 (two diagonal numbers). The answer is 140.
- 140 ÷ 7 = 20 (Divide the remaining number.)
3. The answer is 20.

Example 4

Solve the proportion (find the value of *x*).
x:63 :: 24:72.

$$\frac{x}{63} = \frac{24}{72}$$

$$\frac{x}{63} = \frac{24}{72}$$

$$24 \times 63 = 1512$$
$$1{,}512 \div 72 = 21$$
$$x = 21$$

Steps

1. Rewrite the proportion as a fraction.
2. Multiply the diagonal numbers: 24 × 63 = 1512.
3. Divide the answer (1,512) by the remaining number: 1,512 ÷ 72 = 21.
4. The value for *x* is 21.

Example 5

Solve the proportion (find the value of *x*).

240:60 :: x:12.

$$\frac{240}{60} = \frac{x}{12}$$

$$\frac{240}{60} = \frac{x}{12}$$

$$x = 48$$

HESI Hint

An example of the foil method is to remember "inside x inside and outside x outside."

240:60:: x:12

60 times x :: 240 x 12

60x:: 2880

Divide 60 by both sides to get x by itself
x:: 48

Steps

1. Rewrite the proportion as a fraction.
2. Multiply the diagonal numbers together: 240 × 12 = 2,880.
3. Divide the answer (2,880) by the remaining number: 2,880 ÷ 60 = 48.
4. The answer to x is 48.

Sample Problems

Change the following fractions to ratios:

1. $\frac{22}{91}$
2. $\frac{19}{40}$

Solve the following for *x:*

3. $7:5::91:x$
4. $7:9::x:63$
5. $x:15::120:225$
6. 15:x :: 3:8
7. 360:60 :: 6:x
8. x:81 :: 9:27
9. John buys 3 bags of chips for $4.50. How much will it cost John to buy five bags of chips?
10. The recipe states that 4 cups of sugar will make 144 cookies. How many cups of sugar are needed to make 90 cookies?

Percentages

Vocabulary

Percent: Per hundred (part per hundred).

Example 1

Change the decimal to a **percent:** 0.13 → 13%.

Steps

1. Move the decimal point to the right of the hundredths place (two places).
2. Put the percent sign behind the new number.

Example 2

Change the decimal to a percent: 0.002 → 0.2%.

Steps

1. Move the decimal point to the right of the hundredths place (always two places!).
2. Put the percent sign behind the new number. It is still a percent; it is just a very small percent.

Example 3

Change the percent to a decimal: 85.4% → 0.854.

Steps

1. Move the decimal two spaces away from the percent sign (to the left).
2. Drop the percent sign; it is no longer a percent, but a decimal.

Example 4

Change the percent to a decimal: 75% → 0.75.

Steps

1. The decimal point is not visible, but is always located after the last number.
2. Move the decimal two spaces away from the percent sign (toward the left).
3. Drop the percent sign; the number is no longer a percent, but a decimal.

Example 5

Change the fraction to a percent: $\frac{5}{6}$

$$
\begin{array}{r}
.833 \\
6\overline{)5.000} \\
-48\downarrow\downarrow \\
\hline
20\downarrow \\
-18\downarrow \\
\hline
20
\end{array}
$$

$$0.833 \rightarrow 83.3\%$$

Steps

1. Change the fraction into a division problem and solve.
2. Move the decimal behind the hundredths place in the quotient.
3. Place a percent sign after the new number.

Sample Problems

Change the following decimals to percents.

1. 0.98 =
2. 0.0068 =
3. 0.09 =

Change the following percents to decimals.

4. 58% =
5. 76.3% =
6. 0.03% =

Change the following fractions to percents.

7. $\frac{9}{10}$ =
8. $\frac{4}{5}$ =
9. $\frac{1}{6}$ =
10. $\frac{3}{8}$ =

Using the Percent Formula

HESI Hint

The word *of* usually indicates the whole portion of the percent formula.

Percent formula:

$$\frac{\text{Part}}{\text{Whole}} = \frac{\%}{100}$$

Using this formula will help in all percent problems in which there is an unknown (solving for x).

Example 1

What is 7 out of 8 expressed as a percent?

$$\frac{7}{8} = \frac{\%}{100}$$

$$7 \times 100 = 700$$

$$700 \div 8 = 87.5$$

$$\% = 87.5 \text{ or } 87.5\%$$

Steps

1. Rewrite the problem using the percent formula.
2. Multiply the diagonal numbers together: 7 × 100 = 700.
3. Divide by the remaining number: 700 ÷ 8 = 87.5%.

Example 2

What is 68% of 45?

$$\frac{x}{45} = \frac{68}{100}$$

$$45 \times 68 - 3{,}060$$

$$3{,}060 \div 100 = 30.6$$

$$x = 30.6$$

Steps

1. Rewrite the problem using the percent formula.
2. "Of 45:" 45 is the whole.
3. Multiply the diagonal numbers together: 68 × 45 = 3,060.
4. Divide by the remaining number: 3,060 ÷ 100 = 30.6.
5. x = 30.6 (this is not a percent; it is the part).

Example 3

18 is 50% of what number?

$$\frac{18}{x} = \frac{50}{100}$$

$$18 \times 100 = 1{,}800$$

$$1{,}800 \div 50 = 36$$

$$x = 36$$

Steps

1. Rewrite the problem using the percent formula.
2. We are looking for the **whole** because *of* is indicating an unknown number.
3. Multiply the diagonal numbers together: 18 × 100 = 1800.
4. Divide by the remaining number: 1,800 ÷ 50 = 36.

Fraction	Decimal	Percent
$\frac{1}{2}$	0.50	50%
$\frac{1}{4}$	0.25	25%
$\frac{3}{4}$	0.75	75%
$\frac{1}{5}$	0.20	20%
$\frac{2}{5}$	0.40	40%
$\frac{3}{5}$	0.60	60%
$\frac{4}{5}$	0.80	80%
$\frac{1}{8}$	0.125	12.5%
$\frac{3}{8}$	0.375	37.5%
$\frac{5}{8}$	0.625	62.5%
$\frac{7}{8}$	0.875	87.5%
$\frac{1}{3}$	0.333‾	33.3%
$\frac{2}{3}$	0.666‾	66.6%

Sample Problems

Solve the following percent problems.
1. What is 15 out of 75 as a percent?
2. What is 2 out of 50 as a percent?
3. What is 20 out of 100 as a percent?
4. What is 28% of 100?
5. What is 95% of 20?
6. What is 15.5% of 600?
7. The number 2 is 20% of what number?
8. The number 65 is 25% of what number?
9. The number 9 is 20% of what number?
10. The number 44 is 25% of what number?

12-hour Clock versus Military Time

12-hour clock uses the numbers 1 through 12 with the suffixes AM or PM to represent the hour in a 24-hour period. Military time uses the numbers 00 through 23 to represent the hour in a 24-hour period. The minutes and seconds in 12-hour clock and military time are expressed the same way.

HESI Hint

To convert to military time before noon, simply include a zero before the numbers 1 through 9 for AM. For example, 9:35 AM 12-hour clock time converts to 0935 military time. The zero is not needed when converting 10 AM or 11 AM. If the time is after noon, simply add 12 to the hour number. For example, 1:30 PM 12-hour clock time converts to 1330 military time (1 + 12 = 13). Midnight, or 12 AM, is converted to 0000. Noon, or 12 PM, is converted to 1200.

Table 1-1 summarizes the equivalents between military time and 12-hour clock time.

Military time is written with a colon between the minutes and seconds just as in the 12 hour clock. It can also be expressed with a colon between the hours and the minutes.

Table 1-1

Equivalents for Military Time and 12-hour Clock Time

Military Time	12-hour Clock Time	Military Time	12-hour Clock Time
0000	12:00 AM (Midnight)	1200	12:00 PM (Noon)
0100	1:00 AM	1300	1:00 PM
0200	2:00 AM	1400	2:00 PM
0300	3:00 AM	1500	3:00 PM
0400	4:00 AM	1600	4:00 PM
0500	5:00 AM	1700	5:00 PM
0600	6:00 AM	1800	6:00 PM
0700	7:00 AM	1900	7:00 PM
0800	8:00 AM	2000	8:00 PM
0900	9:00 AM	2100	9:00 PM
1000	10:00 AM	2200	10:00 PM
1100	11:00 AM	2300	11:00 PM

Military time is written as follows:

hoursminutes:seconds	OR	**hours**:minutes:seconds
0932:24 hours	OR	**09**:23:24
1926:56 hours	OR	**19**:26:56 hours

12-hour clock time is written as follows:
hours:minutes:seconds AM or PM
9:32:24 AM
7:26:56 PM

Sample Problems

Convert the following 12-hour clock times to military times.

1. 12:00 AM =
2. 3:30 PM =
3. 11:19:46 AM =
4. 8:22:54 PM =
5. 4:27:33 PM =
6. 2:22:22 AM =

Convert the following military times to 12-hour clock times.

7. 0603:45 hours
8. 1200:00 hours
9. 15:16:42 hours
10. 16:18:00 hours
11. 10:33:29 hours
12. 21:11:34 hours

Algebra

Vocabulary

Variable: A letter representing an unknown quantity (i.e., x).

Constant: A number that cannot change.

Expression: A mathematical sentence containing constants and variables (i.e., $3x - 2$).

Exponent: A number or symbol placed above and after another number or symbol (a superscript or subscript), indicating the number of times to multiply.

Algebra is a process that involves variables and constants. A **variable** is a letter that represents an unknown quantity. A **constant** is a number that cannot change. Using the operations of addition, subtraction, multiplication, and division, we can use algebra to find the value of unknown quantities. Two algebra concepts discussed in this section will be evaluating **expressions** and solving equations for a specific variable.

HESI Hint

When working with algebra, remember to evaluate expressions by performing the "Order of Operations:"

1. Evaluate numbers within parentheses.	$4\cdot(2+3)^2 - 5$
2. Multiply numbers based on any exponents.	$4\cdot(5)^2 - 5$
3. Multiply and divide numbers from left to right.	$4\cdot 25 - 5$
4. Add and subtract numbers from left to right.	$100 - 5$

The variable for these expressions is 95.

Here's a mnemonic to remember the "Order of Operations":

"Please excuse my dear Aunt Sally" helps to remember the correct order of operations.

The order should be Parentheses, Exponents, Multiply, Divide, Add, Subtract.

Evaluating the Expression

- Numbers can be positive (1 or +1) or negative (−1). If a number has no sign (e.g., 1; it usually means it is a positive number).
- Adding positive numbers is similar to addition (e.g., $1 + 3 = 4$).
- Subtracting positive numbers is simple subtraction (e.g., $4 - 3=1$).
- Subtracting a negative number is the same as adding (e.g., $3 - [-1] = 4$); it is written as $3 + 1 = 4$.
- Subtracting a positive $4 - (+3) = 4 - 3= 1$
- Adding a negative number $3 + (-4) = 3 - 4 = -1$

Rules:

- Two like signs become positive signs 3 + (+1) = 3(+1) = 3 + 1 = 4

$$3-(-1)=3+1=4$$

- Two unlike signs become a negative sign 8 + (−2) = 8 − 2 = 6

$$8-(+2)=8-2=6$$

When we substitute a specific value for each variable in the expression and then perform the operations, it's called "evaluating the expression."

Example 1

$$\begin{gathered}\text{Evaluate the expression } ab+c \text{ if } a=4, b=-2, \text{ and } c=7\\(4)(-2)+(7)\\-8+7\\-1\end{gathered}$$

Steps

1. Substitute the numbers into the given expression. Use parentheses when inserting numbers into an expression.
2. Multiply 4 × −2 = −8
3. Add −8 + 7 = −1

Example 2

$$\begin{gathered}\text{Evaluate the expression } -xy(x-y)+y \text{ if } x=4 \text{ and } y=-2\\-(4)(-2)([4]-[-2])+(-2)\\-(-8)(4+2)-2\\8(6)-2\\48-2\\46\end{gathered}$$

Steps

1. Substitute the numbers into the given expression.
2. Multiply 4 × −2 = −8.

3. Change −(−2) to + 2, and + (−2) to −2.
4. Add 4 + 2 = 6
5. Change −(−8) to 8
6. Multiply 8 × 6 = 48
7. Subtract 48 − 2 = 46

Solving Equations for a Specific Variable

To solve equations for a specific variable, perform the operations in the reverse order in which you evaluate expressions.

Example 3

$$\begin{aligned} \text{Solve :} \qquad 4x + 5 &= 17 \\ -5 \quad &\; -5 \\ \frac{4x}{4} &= \frac{12}{4} \\ x &= 3 \end{aligned}$$

Steps

1. Subtract 5 from each side of the equation.
2. Divide both sides by 4.

Example 4

$$\begin{aligned} \text{Solve:} \qquad -7k - 4 &= -21 \\ +4 &= +\ 4 \\ \frac{-7k}{-7} &= \frac{-17}{-7} \\ k &= \frac{17}{7} \end{aligned}$$

Steps

1. Add 4 to both sides.
2. Divide both sides by −7.
3. Simplify. (A negative divided by a negative is a positive.)

Sample Problems

Evaluate the following expressions:

1. $xm - 2m$ if $x = -2$ and $m = -3$
2. $2abc - 3ab$ if $a = 2$, $b = -3$, and $c = 4$
3. $-x(y + z)$ if $x = 4$, $y = -3$, and $z = -5$
4. $-k + h + kh$ if $k = -5$ and $h = -2$
5. $-(a - b)(a - bc)$ if $a = 3$, $b = -4$, and $c = 2$

Solve the following equations for the given variable:

6. $3x - 5 = 10$ solve for x.
7. $-2x - 2 = 14$ solve for x.
8. $2y + 3 = 12$ solve for y.
9. $4x + 5 = -19$ solve for x.
10. $-5 = 6m - 1$ solve for m.

Helpful Information to Memorize

Roman Numerals

I = 1	XX = 20	M = 1,000
II = 2	XXX = 30	$\overline{V}$ = 5,000
III = 3	XL = 40	$\overline{X}$ = 10,000
IV = 4	L = 50	$\overline{L}$ = 50,000
V = 5	LX = 60	$\overline{C}$ = 100,000
VI = 6	LXX = 70	$\overline{D}$ = 500,000
VII = 7	LXXX = 80	$\overline{M}$ = 1,000,000
VIII = 8	XC = 90	
IX = 9	C = 100	
X = 10	D = 500	
XI = 11		
Example 2012 = MMXII		

Measurement Conversions

Temperature
0° Celsius = 32° Fahrenheit (the freezing point of water)
Celsius to Fahrenheit
The temperature T in degrees Fahrenheit (° F) is equal to the temperature T in degrees Celsius (° C) times $\frac{9}{5}$ plus 32: $T_{(°F)} = T_{(°C)} \times 9/5 + 32$ or $T_{(°F)} = T_{(°C)} \times 1.8 + 32$ *Example* $T_{(°F)} = 20°C \times \frac{9}{5} + 32 = 68\ °F$
100° Celsius = 212° Fahrenheit (the boiling point of water)
Fahrenheit to Celsius
0 degrees Fahrenheit is equal to −17.77778 degrees Celsius: 0 ° F = −17.77778 ° C The temperature T in degrees Celsius (° C) is equal to the temperature T in degrees Fahrenheit (° F) minus 32, times $\frac{5}{9}$: $T_{(°C)} = (T_{(°F)} - 32) \times \frac{5}{9}$ or $T_{(°C)} = (T_{(°F)} - 32) \div (\frac{9}{5})$ or $T_{(°C)} = (T_{(°F)} - 32) \div 1.8$ **Example** Convert 68 degrees Fahrenheit to degrees Celsius: $T_{(°C)} = (68°F - 32) \times \frac{5}{9} = 20\ °C$
Length

Metric	English
1 kilometer = 1,000 meters	1 mile = 1,760 yards
1 meter = 100 centimeters	1 mile = 5,280 feet
1 centimeter = 10 millimeters	1 yard = 3 feet
2.54 centimeters = 1 inch	1 foot = 12 inches
Volume and Capacity	

Metric	English
1 liter = 1,000 milliliters	1 gallon = 4 quarts
1 milliliter = 1 cubic centimeter	1 gallon = 128 ounces
	1 quart = 2 pints
	1 pint = 2 cups
	1 cup = 8 ounces
	1 ounce = 30 milliliters (cubic centimeters)
Weight and Mass	

Metric	English
1 kilogram = 1,000 grams	1 ton = 2,000 pounds
1 gram = 1,000 milligrams	1 pound = 16 ounces
	2.2 pounds = 1 kilogram

Answers to Sample Problems

Basic Addition and Subtraction

1. 1,959
2. 980
3. 1,511
4. 200
5. 432
6. 459
7. 108
8. 12,011
9. 13 miles
10. 19

Basic Multiplication (Whole Numbers)

1. 5,922
2. 1,950
3. 7,836
4. 44,330
5. 11,130
6. 21,978
7. 189,150
8. 1,557,270
9. 870
10. 180

Basic Division (Whole Numbers)

1. 12
2. 3,206
3. 1,233
4. 25
5. 628
6. 741
7. 214.75
8. 998.14
9. 9
10. 11

Addition and Subtraction of Decimals

1. 16.75
2. 66.838
3. 948.2
4. 25.26
5. 30.05
6. 10.45
7. 29.41
8. 12.57
9. 3.75
10. 2.5

Multiplication of Decimals

1. 0.01269
2. 786.08
3. 16.863
4. 6252.5
5. 0.287804
6. 32.92
7. 3.7236
8. 0.79423
9. 19.2
10. 4.375

Division of Decimals

1. 120
2. 240
3. 9.375
4. 281
5. 8.23
6. 1,970
7. 0.9
8. 1.2
9. 224
10. 6

Addition of Fractions

1. $\frac{1}{2}$
2. $\frac{17}{21}$
3. $1\frac{3}{10}$
4. $\frac{13}{14}$
5. $1\frac{23}{35}$
6. $9\frac{11}{24}$
7. $6\frac{4}{9}$
8. $15\frac{8}{21}$
9. $4\frac{1}{6}$
10. $25\frac{5}{8}$

Subtraction of Fractions

1. $\frac{1}{20}$
2. $\frac{11}{37}$
3. $\frac{2}{25}$
4. $\frac{1}{54}$
5. $1\frac{7}{10}$
6. $15\frac{1}{18}$
7. $12\frac{3}{7}$
8. $16\frac{3}{4}$
9. $1\frac{3}{8}$ feet
10. $\frac{11}{12}$ cups

Multiplication of Fractions

1. $\frac{2}{5}$
2. $\frac{7}{81}$
3. $4\frac{4}{5}$
4. 7
5. $3\frac{3}{4}$
6. 8
7. $6\frac{2}{3}$
8. $7\frac{1}{2}$
9. $16\frac{1}{2}$
10. $27\frac{13}{16}$

Division of Fractions

1. $5\frac{3}{5}$
2. $1\frac{1}{3}$
3. $5\frac{1}{4}$
4. 5
5. 32
6. 9
7. 3
8. $6\frac{1}{6}$
9. 15
10. 10

Changing Fractions to Decimals

1. 0.2
2. 0.4
3. 0.375
4. 0.8
5. 0.333
6. 1.5
7. 0.3
8. 2.875
9. 11.733
10. 0.44

Changing Decimals to Fractions

1. $\frac{2}{25}$
2. $\frac{1}{40}$
3. $\frac{1}{8}$
4. $\frac{17}{100}$
5. $\frac{3}{10}$
6. $2\frac{3}{4}$
7. $7\frac{7}{100}$
8. $12\frac{1}{10000}$
9. $3\frac{12}{25}$
10. $\frac{11}{40}$

Ratios and Proportions

1. 22:91
2. 19:40
3. $x = 65$
4. $x = 49$
5. $x = 8$
6. $x = 40$
7. $x = 1$
8. $x = 27$
9. $x = \$7.50$
10. $x = 2.5$

Percentages

1. 98%
2. 0.68%
3. 9%
4. 0.58
5. 0.763
6. 0.0003
7. 90%
8. 80%
9. 16.667%
10. 37.5%

Using the Percent Formula

1. 20%
2. 4%
3. 20%
4. 28
5. 19
6. 93
7. 10
8. 260
9. 45
10. 176

12-hour Clock Time versus Military Time

1. 0000 hours OR 00:00 hours
2. 1530 hours OR 15:30 hours
3. 1119:46 hours OR 11:19:46 hours
4. 2022:54 hours OR 20:22:54 hours
5. 1627:33 hours OR 16:27:33 hours
6. 0222:22 hours OR 02:22:22 hours
7. 6:03:45 AM
8. 12:00 PM OR Noon
9. 3:16:42 PM
10. 4:18 PM
11. 10:33:29 AM
12. 9:11:34 PM

Algebra

1. 12
2. −30
3. 32
4. 13
5. −77
6. $x = 5$
7. $x = -8$
8. $y = \frac{9}{2}$ or $y = 4\frac{1}{2}$ or $y = 4.5$
9. $x = -6$
10. $m = -\frac{2}{3}$

Reading Comprehension

CHAPTER OUTLINE

KEY TERMS

Antonym
Assumption
Connotation
Context Clue
Inference
Purpose
Synonym
Tone

Communication, whether written or spoken, sets us apart from all other life forms. We live in an age of instant telecommunication and think nothing of it. Yet, it is the written word that allows a person to record information that can travel across time and distance, to be examined and reexamined. In the health care setting, this is especially true for the health care provider as well as other members of the health care team as this is how information is shared among members of the health care team. The client record is written documentation of what is known of the client, which includes health care history, the evaluation

or assessment, the diagnosis, the treatment, the care, the progress, and, possibly, the outcome. A clear understanding of all client information ensures better health care management for the client. The ability to skillfully read and understand also helps the health care personnel clearly document the client's written record as care is provided. Any student wishing to enter the health care profession must have the ability to read and understand the written word.

Identifying the Main Idea

Identifying the main idea is the key to understanding what has been read and what needs to be remembered. First, identify the topic of the passage or paragraph by asking the question, "What is it about?" Once that question has been answered, ask, "What point is the author making about the topic?" If the reader understands the author's message about the topic, the main idea has been identified.

In longer passages the reader might find it helpful to count the number of paragraphs used to describe what is believed to be the main idea statement. If the majority of paragraphs include information about the main idea statement the reader has chosen, the reader is probably correct. However, if the answer chosen by the reader is mentioned in only one paragraph, the main idea that was chosen is probably just a detail.

Another helpful hint in identifying main ideas is to read a paragraph and then stop and summarize that paragraph. This type of active reading helps the reader focus on the content and can lessen the need to reread the entire passage several times.

Some students find that visualizing as they read helps them remember details and stay focused. They picture the information they are reading as if it were being projected on a big-screen TV. If you do not already do this, try it. Informal classroom experiments have proved that students who visualize while reading comprehension tests easily outscore their counterparts who do not visualize.

HESI Hint

Main ideas can be found in the beginning, in the middle, or at the end of a paragraph or passage. Always check the introduction and conclusion for the main idea.

Finally, not all main ideas are stated. Identify unstated or implied main ideas by looking specifically at the details, examples, causes, and reasons given.

Again, asking the questions stated earlier will help in this task:

- What is the passage about? (Topic)
- What point is the author making about the topic? (Main idea)

Some experts like to compare the main idea with an umbrella covering all or most of the details in a paragraph or passage. The chosen main idea can be tested for accuracy by asking whether the other details will fit under the umbrella. The idea of an umbrella also helps visualize how broad a statement the main idea can be.

Identifying Supporting Details

Writing is made up of main ideas and details. Few individuals would enjoy reading only a writer's main ideas. The details provide the interest, the visual picture, and the examples that sustain a reader's interest.

Often students confuse the author's main idea with the examples or reasons the author gives to support the main idea. These details give the reader a description, the background, or simply more information to support the writer's assertion or main idea. Without these details, the reader would not be able to evaluate whether the writer has made his or her case, nor would the reader find the passage as interesting. In addition to examples, facts and statistics may be used.

The reader's job is to distinguish between the details, which support the writer's main idea, and the main idea itself. Usually the reader can discover clues to help identify details because often an author uses transition words such as *one, next, another, first,* or *finally* to indicate that a detail is being provided.

Finding the Meaning of Words in Context

Even the most avid readers will come across words for which they do not know the meaning. Identifying the correct meanings of these words may be the key to identifying the author's main idea and to fully comprehending the author's meaning. The reader can, of course, stop and use a dictionary or the Thesaurus for these words. However, this is usually neither the most efficient nor the most practical way to approach the unknown words.

There are other options the reader can use to find the meanings of unknown words, and these involve using context clues. The phrase **context clue** refers to the information provided by the author in the words or sentences surrounding the unknown word or words.

Some of the easiest context clues to recognize are as follows:

1. Definition—The author puts the meaning of the word in parentheses or states the definition in the following sentence.
2. **Synonym**—The author gives the reader another word that means the same or nearly the same as the unknown word.
3. **Antonym**—The author gives a word that means the opposite of the unknown word.

HESI Hint

The reader needs to watch for clue words such as *although, but,* and *instead,* which sometimes signal that an antonym is being used.

4. Restatement —The author restates the unknown word in a sentence using more familiar words.
5. Examples —The author gives examples that more clearly help the reader understand the meaning of the unknown word.
6. Explanation —The author gives more information about the unknown word, which better explains the meaning of the word.
7. Word structure —Sometimes simply knowing the meanings of basic prefixes, suffixes, and root words can help the reader make an educated guess about an unknown word.

HESI Hint

When being tested on finding the meaning of a word in the context of a passage, look carefully at the words and sentences surrounding the unknown word. The **context clues** are usually there for the reader to uncover. Once the correct meaning has been chosen, test that meaning in the passage. It should make sense, and the meaning should be supported by the other sentences in the passage or paragraph.

Identifying a Writer's Purpose and Tone

The purposes or reasons for reading or writing are similar for the readers and the writers. Readers read to be entertained, and authors write to entertain. Readers choose to read for information, and writers write to inform. However, in the area of persuasion, a reader can be fooled into believing he/she is reading something objective when in fact the author is trying to influence or manipulate the reader's thinking, which is why it is important for readers to ask the following questions:

1. Who is the intended audience?
2. Why is this being written?

If the writer is trying to change the reader's thinking, encourage the reader to buy something, or convince the reader to vote for someone, the reader can assume the writer's goal is to persuade. More evidence can be found to determine the writer's purpose by identifying specific words used within the passage. Words that are biased, or words that have positive or negative connotations, will often help the reader determine the author's reason for writing. (**Connotation** refers to the emotions or feelings that the reader attaches to words.)

If the writer uses a number of words with negative or positive connotations, the writer is usually trying to influence the reader's thinking about a person, place, or thing. Looking at the writer's choice of words also helps the reader determine the tone of the passage. (An author's **tone** refers to the attitude or feelings the author has about the topic.)

For example, if the author is writing about the Dallas City Council's decision to build waterways on the Trinity River bottom to resemble the San Antonio River Walk and describes this decision as being "inspired" and "visionary," the reader knows the author has positive feelings about the decision. The tone of this article is positive because the words *inspired* and *visionary* are positive words. The reader might also be aware that the author may be trying to influence the reader's thinking.

On the other hand, if the writer describes the council's decision as being "wasteful" and "foolhardy," the reader knows the author has negative feelings about the council's decision. The reader can determine that the tone is unfavorable because of the words the writer chose. Typically, articles with obvious positive or negative tones and connotations will be found on the opinion or editorial page of the newspaper.

Articles or books written to inform should be less biased, and information should be presented in factual format and with sufficient supporting data to allow readers to form their own opinions on the event that occurred.

HESI Hint

When determining the writer's purpose and/or tone, look closely at the

writer’s choice of words. The words are the key clues.

Distinguishing between Fact and Opinion

A critical reader must be an active reader. A critical reader must question and evaluate the writer's underlying assumptions. An **assumption** is a set of beliefs that the writer has about the subject. A critical reader must determine whether the writer's statements are facts or opinions and whether the supporting evidence and details are relevant and valid. A critical reader is expected to determine whether the author's argument is credible and logical.

To distinguish between fact and opinion, the reader must understand the common definitions of those words. A fact is considered something that can be proved (either right or wrong). For example, at the time Columbus sailed for the New World, it was considered a scientific fact that the world was flat. Columbus proved the scientists wrong.

An opinion is a statement that cannot be proved. For example, "I thought the movie *Boyhood* was the best movie ever made" is a statement of opinion. It is subjective; it is the writer's personal opinion. On the other hand, the following is a statement of fact: "The movie *Boyhood* was nominated for an Academy Award for best picture in 2015 but did not win." This statement is a fact because it can be proved to be correct.

Again, the reader must look closely at the writer's choice of words in determining fact or opinion. Word choices that include measurable data and colors are considered factual or concrete words. "Frank weighs 220 pounds" and "Mary's dress is red" are examples of concrete words being used in statements of fact.

If the writer uses evaluative or judgmental words *(good, better, best, worst),* it is considered a statement of opinion. Abstract words *(love, hate, envy)* are also used in statements of opinion. These include ideas or concepts that cannot be measured. Statements that deal with probabilities or speculations about future events are also considered opinions.

Making Logical Inferences

In addition to determining fact and opinion, a critical reader is constantly required to make logical inferences. An **inference** is an educated guess or conclusion drawn by the reader based on the available facts and information. Although this may sound difficult and sometimes is, it is done frequently. A critical reader does not always know whether the inference is correct, but the inference is made based on the reader's own set of beliefs or assumptions.

Determining inferences is a skill often referred to as *reading between the lines.* It is a logical connection that is based on the situation, the facts provided, and the reader's knowledge and experience. The key to making logical inferences is to be sure the inferences are supportable by evidence or facts presented in the reading. This often requires reading the passage twice so that details can be identified. Inferences are not stated in the reading but are derived from the information presented and influenced by the reader's knowledge and experience.

Summarizing

Identifying the best summary of a reading selection is a skill some students may find frustrating. Yet this skill can be mastered easily when the following three rules are used:

1. The summary should include the main ideas from the beginning, middle, and end of the passage.
2. The summary is usually presented in sequence; however, occasionally it may be presented in a different order.
3. The summary must have accurate information. Sometimes a test summary will deliberately include false information. In that case, the critical reader will automatically throw out that test option.

Summary questions will typically take the longest for the student to answer because to answer them correctly the student must go through each summary choice and locate the related information or main idea in the passage itself. Double-checking the summary choices is one way to verify that the reader has chosen the best summary. If the summary choice presents information that is inaccurate or out of order, the reader will automatically eliminate those choices.

HESI Hint

Remember, the summary should include the main ideas of the passage, possibly with some major supporting details. It is a shortened version of the passage that includes all the important information, eliminating the unnecessary and redundant.

Review Questions

Each year, more and more "baby boomers" reach the age of 65 and become eligible for Medicare. As of July 2013, according to the Census Bureau, approximately 14% of the population in the United States is 65 years of age or older. It is projected that this group will increase to over 20% of the population by 2050. As health care costs go up and health care needs increase with age, Medicare is especially important to seniors. Medicare Part A provides assistance with inpatient hospital costs, whereas Medicare Part B helps pay for doctor services and outpatient care. In 2006, Congress enacted Medicare Part D, which today helps many seniors pay for the cost of prescription drugs.

Before the enactment of Medicare Part D, many seniors faced financial hardship in regard to purchasing prescription drugs. Today, it is no longer a question of whether to pay for housing and food or prescription drugs, but which Part D plan provides the best prescription coverage. Although Part D has alleviated many uncertainties, seniors still have concerns. Not all prescription drugs are covered in each plan provided by Part D. Each plan has its own list of covered drugs that can change, requiring seniors to possibly switch coverage every year. Seniors who suffer from multiple medical conditions may not be able to find a plan that covers all their prescribed medications. In addition to a monthly premium paid for Part D, once prescription costs reach $2,960 most prescription plans have a coverage gap (also called the "donut hole"). A coverage gap is a temporary limit on what the prescription plan will pay. The participant is responsible for a percentage of drug costs up to $4,700. This "donut hole" can mean that some seniors limit or stop their medication for the remainder of the program year to reduce costs.

Medicare helps provide seniors with some of the best health care in the world. Yet, the services do come at a huge financial cost. It might behoove younger generations to consider preventive care to improve their own golden years.

1. What is the main idea of the passage?

   A. The high cost of prescription drugs is a difficult financial burden for seniors.

   B. Medicare Part D has many problems and no benefits.

   C. Medicare Part D, along with Part A and Part B, helps seniors afford prescription drugs and better health care.

   D. Senior citizens enrolled in Medicare Part D have no prescription drug concerns.

2. Which of the following is not listed as a detail in the passage?

   A. By the year 2050 the number of seniors over the age of 65 will increase.

   B. Medicare Parts A and B help pay for hospital costs and doctor services.

   C. Seniors are required to enroll in Medicare Part D.

D. Medicare Part D includes a "donut hole."

3. What is the meaning of the word *behoove* as used in the last paragraph?
   A. To be necessary
   B. To be responsible for
   C. To increase
   D. To tell others

4. What is the author's primary purpose in writing this essay?
   A. To inform people how to enroll in Medicare
   B. To persuade seniors to enroll in Medicare Part D
   C. To entertain non–health care professionals
   D. To analyze the provisions of Medicare Part D

5. Identify the overall tone of the essay.
   A. Argumentative
   B. Cautious
   C. Sympathetic
   D. Pessimistic

6. Which of the following statements is an opinion?
   A. Senior citizens pay a monthly insurance premium for Part D coverage.
   B. The high cost of prescription drugs has made life difficult for seniors.
   C. In 2006, Congress enacted Medicare legislation that provides prescription drug coverage.
   D. Not all prescription drugs are covered in each plan provided by Medicare Part D.

7. Which statement would not be inferred by the reader?
   A. Most Americans will never have a need for Medicare and its various parts.
   B. Some age-related illnesses might be averted with preventive care.
   C. Some seniors could find themselves changing their Part D coverage yearly.
   D. The "donut hole" in Part D does create a financial hardship for seniors.

8. Choose the best summary of the passage.
   A. Americans are growing older every year and are requiring more and more health care. Health care professionals can help meet those needs if seniors enroll in Medicare Parts A, B, and D. The three parts of Medicare can ease the financial burden of seniors.
   B. At the age of 65, senior citizens sign up for Medicare Parts A, B, and D, which will cover medical costs up to $2,960 a year. For those seniors who suffer from multiple health issues, the cost is $4,700. Prescription drug care provided through Part D makes life much easier for seniors.
   C. "Baby boomers" are the most common senior citizens requiring health

care. This group is the fastest growing group and will comprise over 20% of the population by 2050. Even though there are concerns about Medicare, Part D ensures that all seniors have the medical coverage they need.

D. Medicare Parts A, B, and D help seniors pay for hospital costs, doctor and outpatient services, and prescription drugs. Even though Part D offers many benefits, there are still concerns about various plans with different covered prescriptions and the "donut hole." For seniors, life with Medicare is better.

Answers to Review Questions

1. C—main idea
2. C—supporting detail
3. A—meaning of word in context
4. D—author's purpose
5. B—author's tone
6. B—fact and opinion
7. A—inferences
8. D —summary

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Vocabulary

Members of the health professions use specific medical terminology to ensure accurate, concise, and consistent communication among all persons involved in the provision of health care. In addition to the use of specific medical terms, many general vocabulary words are used in a health care context. It is essential that students planning to enter the health care field have a basic understanding of these general vocabulary words to ensure accurate communication in a professional setting.

The following list of vocabulary words includes a definition for each word and an example of the word as used in a health care context. Careful study and review of these vocabulary words will help you begin your health profession studies with the ability to communicate in a professional manner.

HESI Hint

Being able to use a wide range of vocabulary skills correctly is considered by some experts to be the best measure of adult IQ.

Abstain: To voluntarily refrain from something.
Example: The dental hygienist instructed the patient to abstain from smoking to improve his breath odor.
Accountable: To be responsible.
Example: Paramedics are accountable for maintaining up-to-date knowledge of resuscitation techniques.
Acute: Sudden, intense.
Example: The nurse administered the prescribed pain medication to the patient who was experiencing acute pain after surgery.
Adhere: To hold fast or stick together.
Example: The tape must adhere to the patient's skin to hold the bandage in place.
Adverse: Undesired, possibly harmful.
Example: Vomiting is an adverse effect of many medications.
Aegis: Control, protection.
Example: Unit staffing decisions are under the aegis of the nurse manager.
Ambivalent: Uncertain, having contradictory feelings.
Example: After learning that she had breast cancer, the patient was ambivalent about having a mastectomy.
Apply: To place, put on, or spread something.
Example: The nurse will apply a medication to the wound before covering the wound with a bandage.
Assent: To give consent; to agree.

Example: The patient was asked to assent to the surgery by signing the informed consent document.

Audible: Able to be heard.

Example: The respiratory therapist noted the patient's audible wheezing as a symptom of the patient's asthma.

Bacteria: Single-celled, microscopic organisms.

Example: The physician ordered a laboratory test to confirm that the patient's illness was caused by bacteria rather than a virus.

Bilateral: Present on two sides.

Example: The unlicensed assistive personnel reported to the nurse that the patient had bilateral weakness in the legs when walking.

Cardiac: Of or relating to the heart.

Example: Smoking increases the risk of cardiac disease.

Cavity: An opening or an empty area.

Example: The nurse inspected the patient's oral cavity for lesions.

Cease: Come to an end or bring to an end.

Example: Because the patient's breathing had ceased, the paramedic began resuscitation measures.

Chronology: Order of events as they occurred; timeline.

Example: The police interviewed witnesses and first responders to determine the chronology of the accident.

Compensatory: Offsetting or making up for something.

Example: When the patient's blood pressure decreased, the paramedic noted that the heart rate increased, which the paramedic recognized as a compensatory action.

Concave: Rounded inward.

Example: The dietician noticed that the patient was very thin and that the patient's abdomen appeared concave.

Concise: Brief, to the point.

Example: When teaching a patient, the nurse tried to be concise so that the instructions would be easy to remember.

Consistency: Degree of viscosity; how thick or thin a fluid is in relation to how it flows.

Example: The respiratory therapist noticed that the mucus the patient was coughing was of a thin, watery consistency.

Constrict: To draw together or become smaller.

Example: The nurse knows that the small blood vessels of the skin will constrict when ice is applied to the skin.

Contingent: Dependent.

Example: The hygienist told the patient that a healthy mouth is contingent on careful daily brushing and flossing.

Contraindication: A reason something is not advisable or should not be done.

Example: The patient's excessive bleeding was a contraindication for discharge from the hospital.

Convulsive: Having or causing convulsions, i.e., violent shaking of the body.

Example: Epilepsy is a convulsive disorder.

Cursory: Quick, perfunctory, not thorough.

Example: During triage, the paramedic gave each accident victim a cursory examination.

Defecate: Expel feces.

Example: The unlicensed assistive personnel helped the patient to the toilet when the patient needed to defecate.

Deficit: A deficiency or lack of something.

Example: The therapist explained that the patient will experience a fluid deficit if the patient continues to perspire heavily during exercise without drinking enough fluids.

Depress: Press downward.

Example: The nurse will depress the patient's skin to see if any swelling is present.

Depth: Downward measurement from a surface.

Example: The physician measures the depth of a wound by inserting a cotton swab into the wound.

Deteriorating: Worsening.

Example: The dental hygienist explains that the condition of the patient's gums is deteriorating and treatment by the dentist is needed right away.

Device: Tool or piece of equipment.

Example: A thermometer is a device used to measure the patient's body temperature.

Diagnosis: Identification of an injury or disease.

Example: The patient received a diagnosis of pancreatitis.

Dilate: To enlarge or expand.

Example: When shining a light in the patient's eyes, the nurse looks to see if both pupils dilate in response to the light.

Dilute: To make a liquid less concentrated.

Example: The pharmacy technician suggests that the patient use fruit juice to dilute a foul-tasting drug so that the medication will be easier to swallow.

Discrete: Distinct, separate.

Example: The paramedic observed several discrete bruise marks on the patient's body.

Distal: Distant; away from the center (such as of the body).

Example: The paramedic suspected that the patient had a dislocated knee and knew it was important to check a distal pulse in the ankle.

Distended: Enlarged or expanded from pressure.

Example: When a blood vessel is distended, the laboratory technician can easily insert a needle to obtain a blood sample.

Dysfunction: Impaired or abnormal functioning.

Example: Family dysfunction may increase when a member experiences an acute physical illness.

Empathy: Ability to share what others are feeling; understanding the feelings of another.

Example: After being diagnosed with cancer, the physician felt more empathy

toward patients with cancer.
Equilibrium: Balance.
Example: The nurse suspected that an ear infection was the cause of the patient's lack of equilibrium.
Etiology: The origin or cause of a disease or condition.
Example: The nurse interviewed the patient to determine the etiology of the patient's food poisoning.
Exacerbate: To make worse or more severe.
Example: The physical therapist recognized that too much exercise would exacerbate the patient's breathing difficulties.
Expand: To increase in size or amount.
Example: The unlicensed assistive personnel turned the patient frequently so that the skin sore would not expand any further.
Exposure: To come in contact.
Example: The nurse taught the parents of a newborn to avoid exposure to people with severe infections.
Extension: Lengthening; unbending a joint.
Example: The physical therapist helped the patient perform extension and flexion exercises.
External: Located outside the body.
Example: The unlicensed assistive personnel measured the amount of blood in the external drain after the patient's surgery.
Fatal: Resulting in death.
Example: The emergency medical technicians arrived too late to save any lives at the scene of a fatal car accident.
Fatigue: Extreme tiredness, exhaustion.
Example: The dietician explained to the patient that eating more iron-rich foods may help reduce feelings of fatigue.
Flexion: Bending a joint.
Example: Arthritis can make flexion of the fingers difficult.
Flushed: Reddened or ruddy appearance.
Example: The therapist observed that the patient's face was flushed after the patient completed the exercises.
Gastrointestinal: Of or relating to the stomach and the intestines.
Example: The patient was diagnosed with a gastrointestinal disease.
Hematologic: Of or relating to blood.
Example: Pregnancy can put a woman at risk for anemia, which is a hematologic disorder.
Hydration: Maintenance of body fluid balance.
Example: The medical assistant explains that adequate hydration helps keep skin soft and supple.
Hygiene: Measures contributing to cleanliness and good health.
Example: The dental assistant teaches patients about good hygiene practices to maintain strong teeth.
Impaired: Diminished or lacking some usual quality or level.
Example: The paramedic stated that the patient's impaired speech was

obvious in the way she slurred her words.

Impending: Occurring in the near future, about to happen.

Example: The nurse manager increased the emergency room staffing in anticipation of accidents being caused by the impending snowstorm.

Impervious: Impenetrable, not allowing anything to pass through.

Example: Standard precautions require the use of impervious gloves when bodily fluids are handled.

Imply: To suggest without explicitly stating.

Example: The look on the administrator's face implied that she was happy about the results of the inspection.

Incidence: Occurrence.

Example: In recent years there has been an increased incidence of infections that do not respond to antibiotics.

Infection: Contamination or invasion of body tissue by pathogenic organisms.

Example: The doctor prescribed antibiotics for the patient with a bacterial infection.

Infer: To conclude or deduce.

Example: When the patient started crying while receiving an injection, the nurse inferred that the patient was in pain.

HESI Hint

The terms *imply* and *infer* are often confused and used interchangeably, but they do not have the same meaning. Remember: The sender of a message *implies*, and the receiver of the message *infers*.

Inflamed: Reddened, swollen, warm, and often tender.

Example: The nurse observed that the skin around the patient's wound was inflamed.

Ingest: To swallow for digestion.

Example: The paramedic may contact the poison control center when providing emergency care for a child who has ingested cleaning fluid.

Initiate: To begin or put into practice.

Example: The nurse decided to initiate safety measures to prevent injury because the patient was very weak.

Insidious: So gradual as to not become apparent for a long time.

Example: The physician explained that the cancer probably started years ago but had not been detected because its spread was insidious.

Intact: In place, unharmed.

Example: The nurse observed that the patient's bandage was intact.

Internal: Located within the body.

Example: The paramedic reported that the patient was unconscious because of internal bleeding.

Invasive: Inserting or entering into a body part.

Example: The laboratory technician is careful when obtaining blood samples because this invasive procedure may cause problems such as infection or bruising.

Kinetic: Of or related to movement.

Example: Kinetic energy from the battery of the medical assistant's tablet caused the device to feel warm to the touch.

Labile: Changing rapidly and often.

Example: Because the child's temperature was labile, the nurse instructed the unlicensed assistive personnel to check the temperature frequently.

Laceration: Cut; tear.

Example: After the accident, the paramedic examined the patient's lacerations.

Latent: Present but not active or visible.

Example: The latent infection produced symptoms only when the patient's condition was weakened from another illness.

Lateral: On the side.

Example: The physical therapist recommended exercises to help increase the strength of the patient's lateral muscles.

Lethargic: Difficult to arouse.

Example: The unlicensed assistive personnel observed that on the morning after a patient received a sleeping pill, the patient was too lethargic to eat breakfast.

Manifestation: An indication or sign of a condition.

Example: The dietician looked for manifestations of poor nutrition, such as excessive weight loss and poor skin condition.

Musculoskeletal: Of or relating to muscle and skeleton.

Example: As a result of overtraining, the athlete suffered a musculoskeletal injury.

Neurologic: Of or relating to the nervous system.

Example: The nurse checked the neurologic status of the patient who was brought to the emergency room after a motorcycle accident.

Neurovascular: Of or relating to the nervous system and blood vessels.

Example: Strokes and aneurysms are neurovascular disorders.

Nutrient: Substance or ingredient that provides nourishment.

Example: The dietician explains that fruits and vegetables contain nutrients that reduce the risk of some cancers.

Occluded: Closed or obstructed.

Example: Because the patient's foot was cold and blue, the nurse reported that the patient's circulation to that foot was occluded.

Ongoing: Continuous.

Example: The nurse instructed the patient that the treatment would be ongoing throughout the patient's entire hospital stay.

Oral: Given through or affecting the mouth.

Example: The patient's instructions stated "no oral fluids for 24 hours following surgery."

Otic: Of the ear.

Example: The physician prescribed an otic medication to treat the patient's ear

infection.

Parameter: A characteristic or constant factor, limit.

Example: The dietician explained that the number of calories needed for energy is one of the important parameters of a healthy diet.

Patent: Open.

Example: The nurse checked to see whether the intravenous needle was patent before giving the patient a medication.

Pathogenic: Causing or able to cause disease.

Example: Viruses and bacteria are pathogenic organisms.

Pathology: Processes, causes, and effects of a disease; abnormality.

Example: The doctor called to request the pathology report for her patient.

Posterior: Located behind; in the back.

Example: The dentist examined the posterior surface of the tooth for a cavity.

Potent: Producing a strong effect.

Example: The potent medication immediately relieved the patient's pain.

Potential: Capable of occurring or likely to occur.

Example: Because the patient was very weak, the therapist felt the patient had a high potential for falling.

Precaution: Preventive measure.

Example: The laboratory technician wore gloves as a precaution against blood contamination.

Precipitous: Rapid, uncontrolled.

Example: The paramedic assisted the pregnant woman during a precipitous delivery in her home.

Predispose: To make more susceptible or more likely to occur.

Example: The dietician explains that high dietary fat intake predisposes some people to heart disease.

Preexisting: Already present.

Example: The nurse notified the physician that the patient has a preexisting condition that might lead to complications during the emergency surgery.

Primary: First or most significant.

Example: The patient's primary concern was when he could return to work after the operation.

Priority: Of great importance.

Example: The laboratory technician was gentle when inserting the needle because it is a high priority to ensure that the patient does not experience excessive pain and discomfort during the procedure.

Prognosis: The anticipated or expected course or outcome.

Example: The physician explained that, with treatment, the patient's prognosis was for a long and healthy life.

Rationale: The underlying reason.

Example: To make sure that the patient will follow the diet instructions, the medical assistant explains the rationale for the low-salt diet.

Recur: To occur again.

Example: To make sure that a tooth cavity does not recur, the dental hygienist instructs the patient to use toothpaste with fluoride regularly.

Renal: Of or relating to the kidneys.
Example: The nurse closely monitored the oral intake and urinary output of the patient with acute renal failure.
Respiration: Inhalation and exhalation of air.
Example: Exercise increases the rate and depth of an individual's respirations.
Restrict: To limit.
Example: The unlicensed assistive personnel removed the water pitcher from the room to assist the patient in following instructions to restrict the intake of fluids.
Retain: To hold or keep.
Example: The nurse administered a medication to prevent the patient from retaining excess body fluid, which might cause swelling.
Serene: Calm, tranquil.
Example: The massage therapist played serene music during the massage session to help the patient relax.
Status: Condition.
Example: The paramedic recognized that the patient's status was unstable, which necessitated immediate transport to the nearest medical center.
Sublingual: Under the tongue.
Example: The patient was prescribed a sublingual medication for chest pain.
Supplement: To take in addition to or to complete.
Example: The dietician instructed the patients to supplement their diets with calcium tablets to help build strong bones.
Suppress: To stop or subdue.
Example: When the child's temperature decreased, the nurse checked to see if any medications had been given that would have suppressed the fever.
Symmetric (symmetrical): Being equal or the same in size, shape, and relative position.
Example: The paramedic observed that the movement of both sides of the patient's chest was symmetrical after the accident.
Symptom: An indication of a problem.
Example: The nurse recognized that the patient's weakness was a symptom of bleeding after surgery.
Syndrome: Group of symptoms that, when occurring together, reflect a specific disease or disorder.
Example: After reviewing the patient's symptoms, which included pain and tingling in the hand and fingers, the physician made a diagnosis of carpal tunnel syndrome.
Therapeutic: Of or relating to the treatment of a disease or a disorder.
Example: Therapeutic diets may include calorie and salt restrictions.
Toxic: Causing harm, poisonous.
Example: The pediatrician recommended that the parents of a toddler keep all toxic substances out of the toddler's reach.
Transdermal: Crossing through the skin.
Example: The physician prescribed a transdermal nicotine patch for a patient participating in the smoking cessation program.

Transmission: Transfer, such as of a disease, from one person to another.

Example: Nurses should wash their hands to prevent the transmission of infections.

Trauma: Injury, wound.

Example: The accident victim had severe facial trauma.

Triage: Process used to determine the priority of treatment for patients according to the severity of a patient's condition and the likelihood of benefit from the treatment.

Example: When the paramedics arrived at the scene of the accident, they had to triage the patients.

Ubiquitous: Being or seeming to be everywhere at once.

Example: The patient noticed the ubiquitous "no smoking" signs in the clinic.

Urinate: Excrete or expel urine.

Example: The patient was instructed to urinate into the container so the nurse could send a urine sample to the laboratory.

Vascular: Of or relating to blood vessels.

Example: The patient underwent vascular surgery for repair of an abdominal aortic aneurysm.

Verbal: Spoken, using words.

Example: The paramedic called in a verbal report on the patient's condition to the emergency room nurse while transporting the patient to the hospital.

Virulent: Extremely harmful and severe.

Example: The virulent infection required an aggressive treatment regimen.

Virus: Microscopic infectious agent capable of replicating only in living cells, usually causing infectious disease.

Example: A person with a cold who goes shopping can transmit the virus to others.

Vital: Essential.

Example: The paramedic knows that it is vital to learn what type of poison was taken when caring for a poisoning victim.

Volume: Amount of space occupied by a fluid.

Example: The nurse recorded the volume of cough syrup administered to the patient.

Review Questions

1. Select the meaning of the underlined word in the sentence. The veterinary technician gave the dog a cursory examination.

   A. Thorough

   B. Concentrated

   C. Quick

   D. Intense

2. Select the meaning of the underlined word in the sentence. The instructions for the otic medication stated, “Instill 3 drops daily.”

   A. Oral

   B. Sublingual

   C. Transdermal

   D. Aural

3. What word meaning “control” best fits in the sentence? Discipline decisions were under the __________ of the school principal.

   A. Aegis

   B. Assent

   C. Etiology

   D. Access

4. What is the best definition of the word *comprehensive*?

   A. Complete

   B. Incomplete

   C. Concise

   D. Exclusive

5. What word meaning “abrupt, intense” best fits in the sentence? The paramedics arrived at the home of a patient who was experiencing _______ chest pain.

   A. Distal

   B. Acute

   C. Chronic

   D. Dynamic

6. What is the best definition of the word *expedite*?

   A. Impel

   B. Empathize

   C. Accelerate

   D. Hinder

7. Select the meaning of the underlined word in the sentence. The nurse was keeping careful watch on the patient's respiration.
   A. Breathing
   B. Skin color
   C. Pulse
   D. Diet
8. Select the meaning of the underlined word in the sentence. The medication was given sublingually.
   A. By nasal inhaler
   B. By injection
   C. Under the tongue
   D. Under the eyelid
9. Select the meaning of the underlined word in the sentence. The rationale for the therapy was to increase the patient's range of motion.
   A. Prescription
   B. Outcome
   C. Goal
   D. Reason
10. Select the meaning of the underlined word in the sentence. The nurse is accountable for patient safety.
   A. Available
   B. Always aware
   C. Responsible
   D. Documenting

Answers to Review Questions

1. C—Quick
2. D—Aural
3. A—Aegis
4. A—Complete
5. B—Acute
6. C—Accelerate
7. A—Breathing
8. C—Under the tongue
9. D—Reason
10. C—Responsible

Grammar

CHAPTER OUTLINE

KEY TERMS

Adjective
Adverb
Clause (independent clause, dependent clause)
Cliché
Compound Sentence
Conjunction
Direct Object
Euphemism
Indirect Object
Interjection
Misplaced Modifier
Noun (common noun, proper noun, abstract noun, collective noun)
Participial Phrase
Participle
Phrase
Predicate

Predicate Adjective
Predicate Nominative
Preposition
Pronoun (personal pronoun, possessive pronoun)
Run-On Sentence
Sentence (declarative, interrogative, imperative, exclamatory)
Sentence Fragment
Sexist Language
Subject
Textspeak
Verb

In the United States, the ability to speak and write the English language using proper grammar is a sign of an educated individual. When people are sick and need information or care from individuals in the health professions, they expect health care workers to be professional, well-educated individuals. It is therefore imperative that anyone in the health care professions understands and uses proper grammar.

Grammar varies a great deal from language to language. English as a second language (ESL) students have an added burden to becoming successful. For example, nursing research literature indicates that ESL nursing students are at greater risk for attrition and failure of the licensing examination. However, this burden can be overcome by learning proper grammar.

This chapter describes the parts of speech, important terms and their uses in grammar, commonly occurring grammatical errors, and suggestions for successful use of grammar.

HESI Hint

From this day forward, listen only to English-speaking radio and television. If at all possible, speak only English at home and with friends.

Eight Parts of Speech

The eight parts of speech are nouns, pronouns, adjectives, verbs, adverbs, prepositions, conjunctions, and interjections.

Noun

A **noun** is a word or group of words that names a person, place, thing, or idea.

Common Noun A common noun is the general, not the particular, name of a person, place, or thing (e.g., *nurse, hospital, syringe*).

Proper Noun A proper noun is the official name of a person, place, or thing (e.g., *Fred, Paris, Washington University*). Proper nouns are capitalized.

Abstract Noun An abstract noun is the name of a quality or a general idea (e.g., *persistence, democracy*).

Collective Noun A collective noun is a noun that represents a group of persons, animals, or things (e.g., *family, flock, furniture*).

Pronoun

A **pronoun** is a word that takes the place of a noun, another pronoun, or a group of words acting as a noun. The word or group of words to which a pronoun refers is called the *antecedent.*

The *students* wanted *their* test papers graded and returned to *them* in a timely manner.

The word *students* is the antecedent of the pronouns *their* and *them.*

Personal Pronoun A personal pronoun refers to a specific person, place, thing, or idea by indicating the person speaking (first person), the person or people spoken to (second person), or any other person, place, thing, or idea being talked about (third person).

Personal pronouns also express number in that they are either singular or plural.

We [first person plural] were going to ask *you* [second person singular] to give *them* [third person plural] a ride to the office.

Possessive Pronoun A possessive pronoun is a form of personal pronoun that shows possession or ownership.

That is *my* book.
That book is *mine.*
That is *his* book.
That book is *his.*

A possessive pronoun does not contain an apostrophe.

HESI Hint

Do **not** use pronouns ending in *self* where they are inappropriate or

unnecessary. Use endings with *self* or *selves* only when there is a noun or personal pronoun in the sentence to relate back to.
- I myself did the entire project.
- Sara did the entire project herself.

Notice that there are no such words as *hisself, theirself,* or *theirselves*.

Adjective

An **adjective** is a word, phrase, or clause that modifies a noun (the *biology* book) or pronoun (He is *nice*.). It answers the question *what kind* (a *hard* test), *which one* (an *English* test), *how many (three* tests), or *how much (many* tests). Verbs, pronouns, and nouns can act as adjectives. A type of verb form that functions as an adjective is a **participle**, which usually ends in *-ing* or *-ed*. Adjectives usually precede the noun or noun phrase that they modify (e.g., *the absent-minded professor*).

Examples

Verbs: The *scowling* professor, the *worried* student, the *broken* pencil

Pronouns: *My* book, *your* class, *that* book, *this* class

Nouns: The *professor's* class, the *biology* class

HESI Hint

Do **not** use the word *more* with certain adjectives, for example, those ending in *er*. It is improper grammar to say or to write *more better* or *more harder*. Likewise, do **not** use the word *most* with adjectives that end in *-est* or *-st*. It is improper grammar to say *most easiest* or *most worst*.

Verb

A **verb** is a word or phrase that is used to express an action or a state of being. A verb is the critical element of a sentence. Verbs express time through a property that is called the *tense*. The three primary tenses are:
- Present—Mary *works*
- Past—Mary *worked*
- Future—Mary *will work*

Some verbs are known as "linking verbs" because they link, or join, the subject of the sentence to a noun, pronoun, or predicate adjective. A linking verb does not show action.
- The most commonly used linking verbs are forms of the verb *to be: am, is, are, was, were, being, been* (e.g., That man *is* my professor.).
- Linking verbs are sometimes verbs that relate to the five senses: *look, sound, smell, feel,* and *taste* (e.g., That exam *looks* difficult.).
- Sometimes linking verbs reflect a state of being: *appear, seem, become, grow,*

turn, prove, and *remain* (e.g., The professor *seems* tired.).

HESI Hint

The following are examples of proper and improper grammar related to verb usage:
It is important that Vanessa *send* **[not** sends] her resumé immediately.
I wish I were **[not** *was*] that smart.
If I were **[not** *was*] you, I'd leave now.

Adverb

An **adverb** is a word, phrase, or clause that modifies a verb, an adjective, or another adverb.

Examples

Verb: The physician operates *quickly*.
Adjective: The nurse wears *very* colorful uniforms.
Another Adverb: The student scored *quite* badly on the test.

Preposition

A **preposition** is a word that shows the relationship of a noun or pronoun to some other word in the sentence. A compound preposition is a preposition that is made up of more than one word. A prepositional phrase is a group of words that begins with a preposition and ends with a noun or a pronoun, which is called the *object* of the preposition. Box 4-1 lists commonly used prepositions.

Examples: Prepositional Phrases

Sam left the classroom *at noon*.
The students learned the basics *of grammar*.

Box 4-1 Commonly Used Prepositions

aboard
about
above
across
after
against
along
amid
among

around
as
at
barring
before
behind
below
beneath
beside
between
beyond
but (except)
by
concerning
considering
despite
down
during
except
following
for
from
in
including
inside
into
like
minus
near
of
off
on
onto
opposite
out
outside
over
past
pending
plus
prior to
throughout
to
toward
under
underneath

unlike
until
up
upon
with
within
without

Conjunction

A **conjunction** is a word that joins words, phrases, or clauses. Words that serve as *coordinating* conjunctions are *and, but, or, so, nor, for,* and *yet* (e.g., The nurse asked to work the early shift, *but* her request was denied.).

Correlative conjunctions work in pairs to join words or phrases (e.g., *Neither* the pharmacist *nor* her assistant could read the physician's handwriting.).

HESI Hint

Correlative conjunctions always stay in the same pairs. Two common pairs are *neither* and *nor* and *either* and *or*. These pairs should not be mixed; it is incorrect to use *neither* with *or* and *either* with *nor*. An easy way to remember this is to think that the two words that start with the letter "n" always go together.

Sometimes, *subordinating* conjunctions join two clauses or thoughts (e.g., *While* the nurse was away on vacation, the hospital flooded.). *While the nurse was away on vacation* is dependent on the rest of the sentence to complete its meaning.

Interjection

An **interjection** is a word or phrase that expresses emotion or exclamation. It does not have any grammatical connection to the other words in the sentence (e.g., *Yikes,* that test was hard. *Whew,* that test was easy.).

Nine Important Terms to Understand

There are nine important terms to understand: Clause, direct object, indirect object, phrase, predicate, predicate adjective, predicate nominative, sentence, and subject.

Clause

A **clause** is a group of words that has a subject and a predicate.

Independent Clause An independent clause expresses a complete thought and can stand alone as a sentence (e.g., *The professor distributed the examinations* as soon as the students were seated.). *The professor distributed the examinations* expresses a complete thought and can stand alone as a sentence.

Dependent Clause A dependent clause begins with a subordinating conjunction (Box 4-2) and does not express a complete thought and therefore cannot stand alone as a sentence. *As soon as the students were seated* does not express a complete thought. It needs the independent clause to complete the meaning and form the sentence.

HESI Hint

Independent clauses are used to write simple and compound sentences. Dependent clauses are added to an independent clause to form complex or compound-complex sentences. When a sentence begins with a dependent clause, use a comma to set it apart from the independent clause. However, when the dependent clause is at the end of a sentence, it should not be preceded by a comma.

The students were late for class, because the bus was delayed at a train crossing. [Incorrect]

The students were late for class because the bus was delayed at a train crossing. [Correct]

Box 4-2 Commonly Used Subordinating Conjunctions

after
because
before
until
since
when

Direct Object

A **direct object** is the person or thing that is directly affected by the action of the verb. A direct object answers the question *what* or *whom* after a transitive verb.
The students watched the professor distribute the examinations.
The professor answers *whom* the students watched.

Indirect Object

An **indirect object** is the person or thing that is indirectly affected by the action of the verb. A sentence can have an indirect object only if it has a direct object. An indirect object answers the question *to whom, for whom, to what,* or *for what* after an action verb.

Indirect objects come between the verb and the direct object.
The professor gave his class the test results.

His class is the indirect object. It comes between the verb *(gave)* and the direct object *(test results),* and it answers the question *to whom.*

Phrase

A **phrase** is a group of two or more words that acts as a single part of speech in a sentence. A phrase can be used as a noun, an adjective, or an adverb. A phrase lacks a subject and a predicate.

Predicate

A **predicate** is the part of the sentence that tells what the subject does or what is done to the subject. It includes the verb and all the words that modify the verb.

Predicate Adjective

A **predicate adjective** follows a linking verb and helps to explain the subject.
My professors are *wonderful.*

Predicate Nominative

A **predicate nominative** is a noun or pronoun that follows a linking verb and helps to explain or rename the subject.
Professors are *teachers.*

Sentence

A **sentence** is a group of words that expresses a complete thought. Every sentence has a subject and a predicate. There are four types of sentences.

Declarative A declarative sentence makes a statement.
Example: I went to the store.
Interrogative An interrogative sentence asks a question.

Example: Did you go to the store?
Imperative An imperative sentence makes a command or request.
Example: Go to the store.
Exclamatory An exclamatory sentence makes an exclamation.
Example: You went to the store!

HESI Hint

Many imperative sentences do not seem to have subjects. An imperative sentence often has an implied subject. For example, when we say *Stop that now,* the subject of the sentence, *you*, is implied *(You stop that now).*

Subject

A **subject** is a word, phrase, or clause that names whom or what the sentence is about.

Ten Common Grammatical Mistakes

Subject-Verb Agreement

A subject must agree with its verb in number. A singular subject requires a singular verb. Likewise, a plural subject requires a plural verb.

Incorrect: The nurses (plural noun) *was* (singular verb) in a hurry to get there.

Correct: The nurses (plural noun) *were* (plural verb) in a hurry to get there.

There are times when the subject-verb agreement can be tricky to determine.

When the Subject and Verb Are Separated

Find the subject and verb and make sure they agree.

Incorrect: The *question* that appears on all of the tests *are* inappropriate.

Correct: The *question* that appears on all of the tests *is* inappropriate.

Ignore any intervening phrases or clauses. Ignore words such as *including, along with, as well as, together with, besides, except,* and *plus*.

Example: The *dean,* along with his classes, *is* going on the tour of the facility.

Example: The *deans,* along with their classes, *are* going on the tour.

When the Subject Is a Collective Noun

A collective noun is singular in form but plural in meaning. It is a noun that represents a group of persons, animals, or things (e.g., *family, audience, committee, board, faculty, herd, flock*).

If the group is acting as a single entity, use a singular verb.

Example: The *faculty agrees* to administer the test.

If the group is acting separately, use a plural verb.

Example: The *faculty are* not in agreement about which test to administer.

When the Subject Is a Compound Subject

Usually, when the subject consists of two or more words that are connected by the word *and,* the subject is plural and calls for a plural verb.

Example: The *faculty* and the *students are* in the auditorium.

When the subject consists of two or more singular words that are connected by the words *or, either/or, neither/nor,* or *not only/but also,* the subject is singular and calls for a singular verb.

Example: Neither the *student* nor the *dean was* on time for class.

When the subject consists of singular and plural words that are connected by the words *or, either/or, neither/nor,* or *not only/but also,* choose a verb that agrees with the subject that is closest to the verb.

Example: Either the students or the teaching assistant is responsible.

Comma in a Compound Sentence

A **compound sentence** is a sentence that has two or more independent clauses.

Each independent clause has a subject and a predicate and can stand alone as a sentence. When two independent clauses are joined by a coordinating conjunction such as *and, but, or,* or *nor,* place a comma before the conjunction.

Example: The professor thought the test was too easy, *but* the students thought it was too hard.

Run-On Sentence

A **run-on sentence** occurs when two or more complete sentences are written as though they were one sentence.

Example: The professor thought the test was too easy the students thought it was too hard.

A comma splice is one kind of run-on sentence. It occurs when two independent clauses are joined by only a comma.

Example: The professor thought the test was too easy, the students thought it was too hard.

The problem can be solved by replacing the comma with a dash, a semicolon, or a colon; by adding a coordinating conjunction; or by making two separate sentences.

Pronoun Case

Is it correct to say, "It was *me*" or "It was *I*"; "It must be *they*" or "It must be *them*"?

The correct pronoun to use depends on the pronoun's case. *Case* refers to the form of a noun or pronoun that indicates its relation to the other words in a sentence. There are three cases: *nominative, objective,* and *possessive.* The case of a personal pronoun depends on the pronoun's function in the sentence. The pronoun can function as a subject, a complement (predicate nominative, direct object, or indirect object), an object of a preposition, or a replacement for a possessive noun.

Examples: Pronoun Use

- When the pronoun is the subject

  I studied for the examination.

  I is the subject of the sentence. Therefore use the nominative form of the pronoun.

- When pronouns are the subject in a compound subject

  Is it correct to say, **"He and I** went to the conference" or **"Him and me** went to the conference"?

  Is it accurate to say, **"John and me** worked through the night" or **"John and I** worked through the night"?

  Is it proper to say, **"Her and Maria** liked the chocolate-covered toffee" or **"She and Maria** liked the chocolate-covered toffee"?

Knowing which pronoun is accurate requires understanding of how the pronoun is used in the sentence, so we know to use the nominative case.

Therefore *He and I, I,* and *She* are the accurate forms of the pronouns.

HESI Hint

When choosing a pronoun that is in a compound subject, sometimes it is helpful to say the sentence without the conjunction and the other subject. We would not say, ***Him** went to the conference* or ***Me** worked through the night* or ***Her** liked the chocolate-covered toffee.* We would, however, say, ***He** went to the conference* and ***I** worked through the night* and ***She** liked the chocolate-covered toffee.*

HESI Hint

It is considered polite to place the pronoun *I* last in a series: *Luke, Jo, and **I** strive to do a good job.*

- When the pronoun is the object of the preposition
  Susan gave the results of the test to them.
  The pronoun *them* is the object of the preposition *to.* When the object of the preposition is a compound object, as in *"Susan gave the results of the test to **Jo and me,**"* the objective form of the pronoun is used.
- When the pronoun replaces a possessive noun
  That desk is hers.
  The possessive pronoun *hers* is used to replace a possessive noun. For example, suppose there is a desk that belongs to Holly. We would say,
  That desk belongs to Holly. That is Holly's desk. That desk is Holly's. That desk is hers.

HESI Hint

Do not use an apostrophe with a possessive pronoun. There are no such words as *her's* or *their's.*

Pronouns That Indicate Possession

The possessive forms of personal pronouns have their own possessive forms, as shown in Table 4-1. Do not confuse these possessive pronouns with contractions that are similarly pronounced or spelled. Examples are shown in Table 4-2.

Incorrect Apostrophe Usage

Apostrophes are used to show possession or to show that letters have been

omitted (i.e., a contraction). Apostrophes are not used to make a word plural, including years and surnames.

Table 4-1

Possessive Personal Pronouns

Pronoun	Possessive Forms	
I	My	Mine
He	His	His
She	Her	Hers
We	Our	Ours
You	Your	Yours
They	Their	Theirs
It	Its	Its

Table 4-2

Common Possessive Pronouns and Similar Contractions

Possessive Pronoun	Contraction
Its (belonging to *it*)	It's (it is, it has)
Their (belonging to *them*)	They're (they are)
Whose (belonging to *whom*)	Who's (who is, who has)
Your (belonging to *you*)	You're (you are)

Examples of plurals: during the 1980s, from the Smiths, with the Inezes

Examples of possessives:

Singular: 1980's highest grossing film, Mr. Smith's home, Inez's car

Plural: the 1980s' highest grossing film, the Smiths' home, the Inezes' cars

Comma in a Series

Use a comma to separate three or more items in a series or list. A famous dedication makes the problem apparent: "To my parents, Ayn Rand and God." Because of the comma placement, it appears as though Ayn Rand and God are the parents. Place a comma between each item in the list and before the conjunction to avoid confusion.

Example: The nursing student took classes in English, biology, and chemistry.

Unclear or Vague Pronoun Reference

An unclear or vague pronoun reference makes a sentence confusing and

difficult to understand.

Example: The teacher and the student knew that she was wrong.

Who was wrong: the teacher or the student? The meaning is unclear. Rewrite the sentence to avoid confusion.

Example: The teacher and the student knew that the *student* was wrong.

Sentence Fragments

Sentence fragments are incomplete sentences.

Example: While the students were taking the test.

The students were taking the test is a complete sentence. However, use of the word *while* turns it into a dependent clause. In order to make the fragment a sentence, it is necessary to supply an independent clause.

Example: While the students were taking the test, the professor walked around the classroom.

HESI Hint

Other words that commonly introduce dependent clauses are *among, because, although,* and *however.*

Misplaced Modifier

Misplaced modifiers are words or groups of words that are not located properly in relation to the words they modify.

Example: I fear my teaching assistant may have discarded the test I was grading in the trash can.

Was the test being graded in the trash can?

The modifier *in the trash can* has been misplaced. The sentence should be rewritten so that the modifier is next to the word, phrase, or clause that it modifies.

Example: I fear the test I was grading may have been discarded in the trash can by my teaching assistant.

One type of misplaced modifier is a dangling participial phrase. A **participial phrase** is a phrase that is formed by a participle, its object, and the object's modifiers; the phrase functions as an adjective. A participial phrase modifies the noun that either directly precedes or directly follows the phrase. When the participial phrase directly precedes or directly follows a noun that it does not modify, the phrase is called a *dangling participial phrase.*

Example: Taking the patient's symptoms into account, a diagnosis was made by the physician.

The participial phrase *taking the patient's symptoms into account* is intended to modify the noun *physician;* however, because the phrase is placed closest to *diagnosis,* it appears to be modifying *diagnosis* instead of *physician.* Therefore, the sentence as it is written states that the diagnosis took the patient's symptoms

into account, which is impossible.

Example: Taking the patient's symptoms into account, the physician made a diagnosis.

Five Suggestions for Success

Eliminate Clichés

Clichés are expressions or ideas that have lost their originality or impact over time because of excessive use. Examples of clichés are *blind as a bat, dead as a doornail, flat as a pancake, raining cats and dogs, keep a stiff upper lip, let the cat out of the bag, sick as a dog, take the bull by the horns, under the weather, white as a sheet,* and *you can't judge a book by its cover.*

Clichés should be avoided whenever possible because they are old, tired, and overused. If tempted to use a cliché, endeavor to rephrase the idea.

Eliminate Euphemisms

A **euphemism** is a mild, indirect, or vague term that has been substituted for one that is considered harsh, blunt, or offensive. In many instances, euphemisms are used in a sympathetic manner to shield and protect. Some people refuse to refer to someone who has died as "dead." Instead, they say that the person has *passed away* or *gone to be with the Lord.* Euphemisms should be eliminated, and we should try to speak and write more accurately and honestly using our own words whenever appropriate.

It is also essential to use accurate and anatomically correct language when referring to the body, a body part, or a bodily function. To do otherwise is unprofessional and tactless.

Eliminate Sexist Language

Sexist language refers to spoken or written styles that do not satisfactorily reflect the presence of women in our society. Such language can suggest a sexist attitude on the part of the speaker or writer. Some believe that making men the default option is degrading and patronizing to women. In general, it is no longer considered appropriate to use *he* or *him* when referring to a hypothetical person. This can be especially important in contexts that refer to, for example, a physician as *he* or the nurse as *she.* In order to avoid such stereotypes, try to use gender-neutral titles that do not specify a particular gender. For example, use *firefighter* instead of *fireman, mail carrier* instead of *mailman, ancestors* instead of *forefathers, chair* instead of *chairman, supervisor* instead of *foreman, police officer* instead of *policeman,* and so on. Do not use terms such as *female doctor* or *male nurse* unless identifying the gender is necessary or appropriate. Similarly, do not use phrases such as *doctors and their wives;* use *doctors and their spouses* instead. If the idea is true that language shapes our thought processes, we would do well to eliminate these sexist forms from our language.

HESI Hint

Attempts to eliminate sexist language have created problems because often the word *his* is replaced with the word *their*. For example, *The doctor helps their patients.* However, this is grammatically incorrect because *their* is a plural pronoun that is being used in place of a singular noun. If the gender of the doctor is known, it is appropriate to use *his* or *her*. *The doctor helped her patients.* If the gender is not known, it is better to reword the sentence to avoid incorrect grammar, as well as sexist language.

- Doctors help their patients.
- The patients are helped by their doctor.

Eliminate Profanity and Insensitive Language

Insensitive and obscene language can be insulting and cruel. What we say does make a difference. The nursery rhyme we learned in our youth, "Sticks and stones may break my bones, but words will never hurt me," is simply not true. Ask anyone who has been on the receiving end of language that is patronizing or demeaning. Because language constantly changes, sometimes we can be offensive without even realizing that we have committed a blunder. In the age of an "anything goes" attitude for television, music lyrics, and the Internet, it is hard to know exactly what constitutes offensive language.

We need to be sensitive to language that excludes or emphasizes a person or group of people with reference to race, sexual orientation, age, gender, religion, or disability. We would all do well to remember another adage from childhood: The Golden Rule. Its message is clear: Respect the dignity of every human being, and treat others as you would like to be treated.

Eliminate Textspeak

Textspeak is language that is often used in text messages, emails, and other forms of electronic communication; it consists of abbreviations, slang, emoticons, and acronyms. With the pervasiveness of social media and text messaging, the use of textspeak may be second nature. However, it is important to be aware of when it is creeping into all electronic communication. Although textspeak is acceptable in informal communication, it is inappropriate to use textspeak in formal communication, such as in academic and professional settings. Just as use of proper grammar is taken as a sign of intelligence, use of textspeak can be taken as a sign of laziness.

Fifteen Troublesome Word Pairs

Affect versus Effect

Affect is normally used as a verb that means "to influence or to change" (The chemotherapy *affected* [changed] my daily routine.). As a noun, *affect* is an emotional response or disposition (The troubled teenager with the flat *affect* [disposition] attempted suicide).

Effect may be used as a noun or a verb. As a noun, it means "result or outcome" (The chemotherapy had a strange *effect* [result] on me). As a verb, it means "to bring about or accomplish" (As a result of the chemotherapy, I was able to *effect* [bring about] a number of changes in my life).

Among versus Between

Use *among* to show a relationship involving more than two persons or things being considered as a group (The professor will distribute the textbooks *among* the students in his class).

Use *between* to show a relationship involving two persons or things (I sit *between* Holly and Jo in class), to compare one person or thing with an entire group (What's the difference between this book and other grammar books?), or to compare more than two things in a group if each is considered individually (I can't decide *between* the chemistry class, the biology class, and the anatomy class).

Amount versus Number

Amount is used when referring to things in bulk (The nurse had a huge *amount* of paperwork).

Number is used when referring to individual, countable units (The nurse had a *number* of charts to complete).

Good versus Well

Good is an adjective. Use *good* before nouns (He did a *good* job) and after linking verbs (She smells *good*) to modify the subject. *Well* is usually an adverb. When modifying a verb, use the adverb *well* (She plays softball *well*). *Well* is used as an adjective only when describing someone's health (She is getting *well*).

HESI Hint

To say that you feel well implies that you are in good health. To say that you are good or that you feel good implies that you are in good spirits.

Bad versus Badly

Apply the same rule for *bad* and *badly* that applies to good and well. Use *bad* as an adjective before nouns (He is a bad teacher) and after linking verbs (That smells bad) to modify the subject. Use *badly* as an adverb to modify an action verb (The student behaved *badly* in class).

HESI Hint

Do not use *badly* (or other adverbs) when using linking verbs that have to do with the senses. Say, "You felt *bad.*" To say, "You felt *badly*" implies that something was wrong with your sense of touch. Say, "The mountain air smells wonderful." To say, "The mountain air smells wonderfully" implies that the air has a sense of smell that is used in a wonderful manner.

Bring versus Take

Bring conveys action toward the speaker—to carry from a distant place to a near place (Please *bring* your textbooks to class).

Take conveys action away from the speaker—to carry from a near place to a distant place (Please *take* your textbooks home).

Can versus May (Could versus Might)

Can and *could* imply ability or power (I *can* make an A in that class). *May* and *might* imply permission (You *may* leave early) or possibility (I *may* leave early).

Farther versus Further

Farther refers to a measurable distance (The walk to class is much *farther* than I expected). *Further* refers to a figurative distance and means "to a greater degree" or "to a greater extent" (I will have to study *further* to make better grades). *Further* also means "moreover" *(Further/Furthermore,* let me tell you something) and "in addition to" (The student had nothing *further* to say).

Fewer versus Less

Fewer refers to number—things that can be counted or numbered—and is used with plural nouns (The professor has *fewer* students in his morning class than he has in his afternoon class).

Less refers to degree or amount—things in bulk or in the abstract—and is used with singular nouns *(Fewer* patients mean *less* work for the staff). *Less* is also used when referring to numeric or statistical terms (It's *less* than 2 miles to school. He scored *less* than 90 on the test. She spent *less* than $400 for this class. I am *less* than 5 feet tall.).

Hear versus Here

Hear is a verb meaning "to recognize sound by means of the ear" (I *hear* the music playing). *Here* is most commonly used as an adverb meaning "at or in this place" (The test will be *here* tomorrow).

i.e. versus e.g

The abbreviation *i.e.* (that is) is often confused with *e.g.* (for example); *i.e.* specifies or explains (I love to study chemistry, *i.e.*, the science dealing with the composition and properties of matter), and *e.g.* gives an example (I love to study chemistry, *e.g.*, chemical equations, atomic structure, and molar relationships).

Learn versus Teach

Learn means "to receive or acquire knowledge" (I am going to *learn* all that I can about nursing). *Teach* means "to give or impart knowledge" (I will *teach* you how to convert decimals to fractions).

Lie versus Lay

Lie means "to recline or rest." The principal parts of the verb are *lie, lay, lain,* and *lying.* Forms of *lie* are never followed by a direct object.

Examples

- I *lie* down to rest.
- I *lay* down yesterday to rest.
- I had *lain* down to rest.
- I was *lying* on the sofa.

Lay means "to put or place." The principal parts of the verb are *lay, laid, laid,* and *laying.* Forms of *lay* are followed by a direct object.

Examples

- I *lay* the book on the table.
- I *laid* the book on the table yesterday.
- I have *laid* the book on the table before.
- I am *laying* the book on the table now.

HESI Hint

To help determine whether the use of *lie* or *lay* is appropriate in a sentence, substitute the word in question with "place, placed, placing" (whichever is appropriate). If the substituted word makes sense, the equivalent form of *lay* is correct. If the sentence doesn't make sense with the substitution, the

equivalent form of *lie* is correct.

Which versus That

Which is used to introduce nonessential clauses, and *that* is used to introduce essential clauses. A nonessential clause adds information to the sentence but is not necessary to make the meaning of the sentence clear. Use commas to set off a nonessential clause. An essential clause adds information to the sentence that is needed to make the sentence clear. Do not use commas to set off an essential clause

Example: The hospital, *which flooded last July,* is down the street.

In this case, the phrase *which flooded last July* is a nonessential clause that is simply providing more information about the hospital.

Example: The hospital *that flooded last July* is down the street; the other hospital is across town.

In this case, the phrase *that flooded last July* is an essential clause because the information distinguishes the two hospitals as the one that flooded and the one that did not.

Who versus Whom

Who and *whom* serve as interrogative pronouns and relative pronouns. An interrogative pronoun is one that is used to form questions, and a relative pronoun is one that relates groups of words to nouns or other pronouns.

Examples

- *Who* is getting an A in this class? (Interrogative)
- Susan is the one *who* is getting an A in this class. (Relative)
- To *whom* shall I give the textbook? (Interrogative)
- Susan, *whom* the professor favors, is very bright. (Relative)

Who and *whom* may be singular or plural.

Examples

- *Who* is getting an A in this class? (Singular)
- *Who* are the students getting As in this class? (Plural)
- *Whom* did you say is passing the class? (Singular)
- *Whom* did you say are passing the class? (Plural)

Who is the nominative case. Use it for subjects and predicate nominatives.

HESI Hint

Use *who* or *whoever* if *he, she, they, I,* or *we* can be substituted in the *who* clause.

Who passed the chemistry test? *He/she/they/I* passed the chemistry test.

Whom is the objective case. Use it for direct objects, indirect objects, and objects of the prepositions.

HESI Hint

Use *whom* or *whomever* if *him, her, them, me,* or *us* can be substituted as the object of the verb or as the object of the preposition in the *whom* clause.

To *whom* did the professor give the test? He gave the test to *him/her/them/me/us.*

Summary

Review this chapter and ask yourself whether your use of the English language reflects that of an educated individual. If so, congratulations! If not, study the content of this chapter, and your scores on the HESI Admission Assessment are likely to improve.

Review Questions

1. Which of the following sentences is grammatically correct?
   A. After receiving intravenous antibiotics, Jarod's health improved.
   B. Growing up, Tom's father always read Tom a bedtime story.
   C. Leaving the door open behind her, Meg stepped into the room.
   D. Before traveling abroad, passports were obtained by the students.
2. Which word from the following sentence is an adjective?

   The nurse leisurely changed from green scrubs into street clothes.
   A. leisurely
   B. scrubs
   C. changed
   D. street
3. Which of the following sentences is grammatically incorrect?
   A. The Lee's had dinner at the Jones home.
   B. The Lees had dinner at the Joneses' home.
   C. The Lees had dinner at the Jone's home.
   D. The Lees's had dinner at the Jones' home.
4. The following sentence contains which type of word or phrase? It's okay; brb.
   A. Textspeak
   B. Euphemism
   C. Possessive
   D. Plural
5. Select the best words for the blanks in the following sentence.

   If I ___ hit a home run, I ___ be chosen for the baseball team.
   A. may, can
   B. may, might
   C. can, may
   D. can, could
6. Which of the following sentences contains a euphemism?
   A. The man said that his friend's dog was a jerk.
   B. The veterinarian told the woman that her cat bounced back.
   C. The family decided to adopt a pet from a no-kill shelter.
   D. The extensively injured dog was put to sleep.
7. Which of the following sentences contains an interjection?
   A. I hope you have finished digging your well.

B. I hope you are feeling well.

C. Well, I hope you are happy.

D. I hope you perform well on the test.

8. Which word is used incorrectly in the following sentence?

To who should the letter be addressed?

A. Who

B. Should

C. Letter

D. Addressed

9. Select the best word for the blank in the following sentence.

He couldn't ______ the speaker's words because of the nearby airport noise.

A. here

B. hear

C. comprehend

D. understand

10. What word is used incorrectly in this sentence?

The six students in the class discussed the test results between themselves.

A. discussed

B. results

C. between

D. themselves

Answers to Review Questions

1. C
2. D
3. B
4. A
5. C
6. D
7. C—In this sentence *well* expresses emotion and does not have a grammatical connection to the rest of the sentence.
8. A—*Who* should be *whom* in this sentence because it is the object of the preposition *to.*
9. B—*Hear* means to recognize sound by means of the ear. *Here* is a site differentiation. C and D would fit in the sentence, but the reference to airport noise makes B the best choice.
10. C—*Between* implies only two people. The correct word to use in the

sentence would be *among*. A, B, and D are used correctly.

Biology

CHAPTER OUTLINE

KEY TERMS

Alleles
Amino Acids
Binary Fission
Chromosomes
Codon
Cytokinesis
Deoxyribonucleic Acid (DNA)
Electron Transport Chain
Glycolysis
Golgi Apparatus
Heterozygous
Homozygous
Interphase

Citric Acid Cycle (also called Krebs Cycle)
Meiosis
Messenger RNA (mRNA)
Metabolic Pathway
Metaphase Plate
Mitosis
Organelles
Phagocytosis
Phospholipids
Photosynthesis
Punnett Square
Ribonucleic Acid (RNA)
Rough ER
Smooth ER
Steroids
Stop Codon
Transcription
Transfer RNA (tRNA)

Biology is the scientific study of life therefore comprehending its basic components is important for understanding injuries and diseases. Members of the health professions naturally deal with biology, whether it requires knowing the structure of a cell, understanding how a molecule will react to a medication or treatment, or comprehending how certain organisms in the body function. Prospective students desiring to enter one of the health professions should have a basic knowledge of biology.

This chapter reviews the structure and reactions of cells and molecules. The concepts of cellular respiration, photosynthesis, cellular reproduction, and genetics are also presented.

Biology Basics

In biology, there is a hierarchic organizational system for nomenclature. In this system, kingdom is the largest and most inclusive category while species is the most restrictive category. The order is as follows:

- Kingdom
- Phylum
- Class
- Order
- Family
- Genus
- Species

Science is a process. For an experiment to be performed, the following steps (commonly called the Scientific Method) must be taken:

- The first step is observation. New observations are made and/or previous data are studied.
- The second step is hypothesis, which is a statement or explanation of certain events or happenings.
- The third step is the experiment, which is a repeatable procedure of gathering data to support or refute the hypothesis.
- The fourth step in the scientific process is the conclusion, where the data and its significance are fully explained.

Water

All life, and therefore biology, occurs in a water based (or aqueous) environment. The water molecule consists of two hydrogen atoms covalently bonded to one oxygen atom. The most significant aspect of water is the polarity of its bonds that allow for hydrogen bonding between molecules. This type of intermolecular bonding has several resulting benefits. The first of these is water's high specific heat.

The specific heat is the amount of heat necessary to raise the temperature of 1 gram of that molecule by 1° Celsius. Water has a relatively high specific heat value, due to the extent of hydrogen bonding between water molecules, which allows water to resist shifts in temperature. One powerful benefit is the ability of oceans or large bodies of water to stabilize climates.

Hydrogen bonding also results in strong cohesive and adhesive properties. Cohesion is the ability of a molecule to stay bonded or attracted to another molecule of the same substance. A good example is how water tends to run together on a newly waxed car. Adhesion is the ability of water to bond to or attract other molecules or substances. When water is sprayed on a wall, some of it sticks to the wall. That is adhesion.

When water freezes, it forms a lattice crystal. This causes the molecules to spread apart, resulting in the phenomenon of ice floating in water. Water is unique in this regard since most solids do not float on the liquid form of their substance because the molecules pack tighter in the solid form.

The polarity of water also allows it to act as a versatile solvent. Water can be used to dissolve a number of different substances (Figure 5-1).

Biologic Molecules

There are multitudes of molecules that are significant to biology. The most important molecules are carbohydrates, lipids, proteins, and nucleic acids.

Carbohydrates

Carbohydrates are generally long chains, or polymers, of sugars. They have many functions and serve many different purposes. The most important of these are storage, structure, and energy. Carbohydrates form the backbone of important molecules such as DNA and RNA.

Lipids

Lipids are better known as fats, but specifically they are fatty acids, phospholipids, and steroids.

Fatty Acids Fatty acids vary greatly but simply are grouped into two categories: saturated and unsaturated. Saturated fats contain no double bonds in their hydrocarbon tail. Conversely, unsaturated fats have one or more double bonds. As a result, saturated fats are solid, whereas unsaturated fats are liquid at room temperature. Saturated fats are those the general public considers detrimental; cardiovascular problems are likely associated with diets that contain high quantities of saturated fats.

Phospholipids Phospholipids consist of two fatty acids of varying length bonded to a phosphate group. The phosphate group is charged and therefore polar and soluable in water, whereas the hydrocarbon tail of the fatty acids is nonpolar and nonsoluable in water. This quality is particularly important in the function of cellular membranes. The molecules organize in a way that creates a barrier that protects the cell.

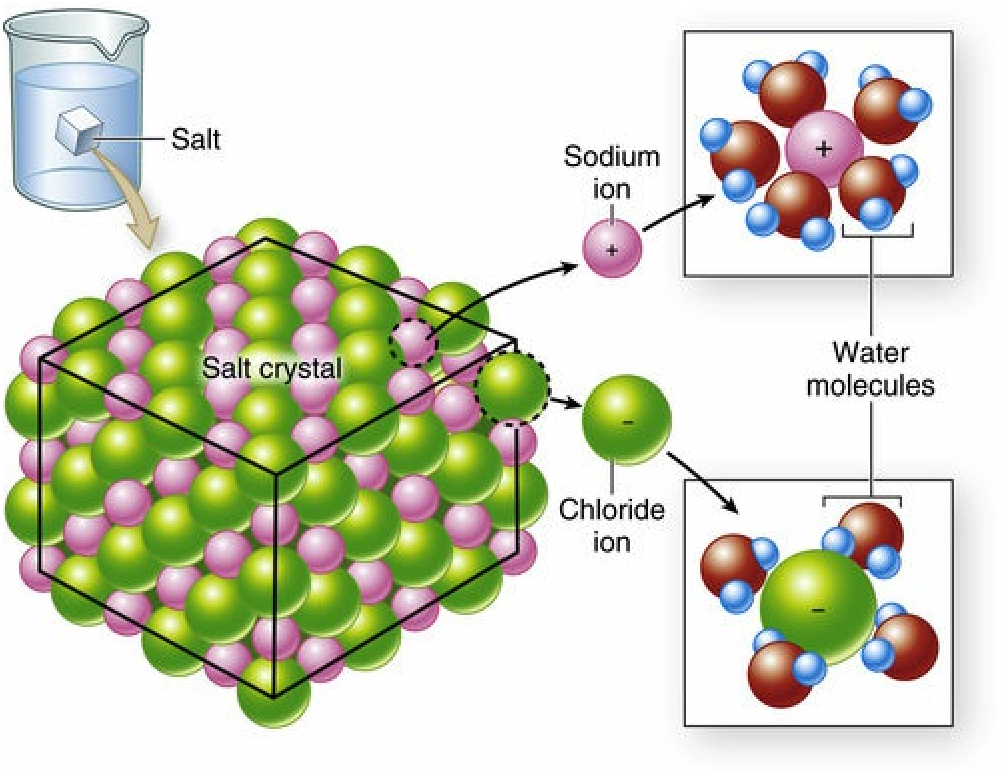

FIGURE 5-1 Water as a solvent. The polar nature of water *(blue)* favors ionization of substances in solution. Sodium (Na^+) ions *(pink)* and chloride (Cl^-) ions *(green)* dissociate in the solution. (From Patton KT, Thibodeau GA: *Anatomy and physiology*, ed 9, St Louis, 2016, Mosby.)

Steroids The last of the lipids are **steroids.** They are a component of membranes, but more important, many are precursors to significant hormones and drugs.

Proteins

Proteins are the most significant contributor to cellular function. They are polymers of 20 molecules called **amino acids.** Proteins are complex, consist of several structure types, and are the largest of the biologic molecules. Enzymes are particular types of proteins that act to catalyze different reactions or processes. Nearly all cellular function is catalyzed by some type of enzyme.

Nucleic Acids

Nucleic acids are components of the molecules of inheritance. **Deoxyribonucleic acid (DNA)** is a unique molecule specific to a particular organism and contains the code that is necessary for replication (Figure 5-2). **Ribonucleic acid (RNA)** is used in transfer of information from DNA to protein level and as a messenger in most species of the genetic code.

Metabolism

Metabolism is the sum of all chemical reactions that occur in an organism. In a cell, reactions take place in a series of steps called **metabolic pathways,** progressing from a standpoint of high energy to low energy. All of the reactions are catalyzed by the use of enzymes.

The Cell

The cell is the fundamental unit of biology. There are two types of cells: prokaryotic and eukaryotic cells. Cells consist of many components, most of which are referred to as **organelles.** Figure 5-3 illustrates a typical cell.

Prokaryotic cells lack a defined nucleus and do not contain membrane-bound organelles. Eukaryotic cells have a membrane-enclosed nucleus and a series of membrane-bound organelles that carry out the functions of the cell as directed by the genetic information contained in the nucleus. In other words, prokaryotic cells do not have membrane-bound organelles, whereas eukaryotic cells do. The eukaryotic cell is the more complex of the two cell types.

There are several different organelles functioning in a cell at a given time; only the major ones are considered here.

Nucleus

The first of the organelles is the nucleus, which contains the DNA of the cell in organized masses called **chromosomes.** Chromosomes contain all of the genetic information for the regeneration (repair and replication) of the cell, as well as all instructions for the function of the cell. Every organism has a characteristic number of chromosomes specific to the particular species.

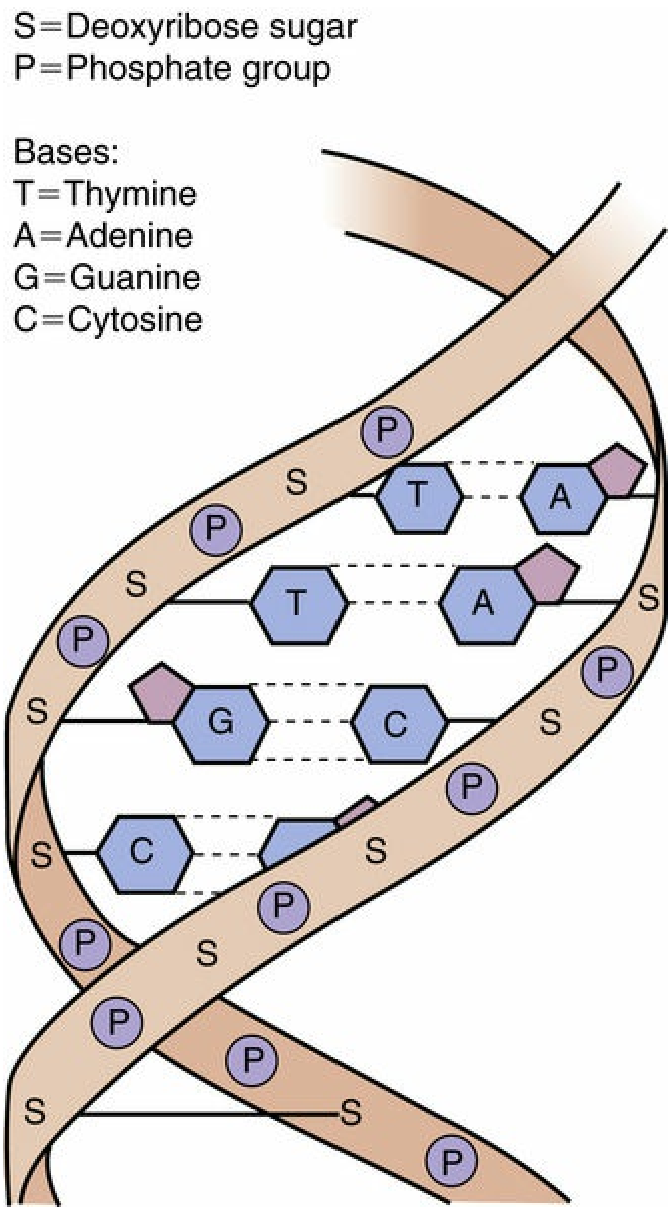

FIGURE 5-2 The DNA molecule. Representation of the DNA double helix showing the general structure of a nucleotide and the two kinds of "base pairs": adenine (A) with thymine (T) and guanine (G) with cytosine (C). (From Applegate: *The anatomy and physiology learning system,* ed 4, St Louis, 2011, Saunders.)

Ribosomes

Ribosomes are organelles that read the RNA produced in the nucleus and translate the genetic instructions to produce proteins. Cells with a high rate of protein synthesis generally have a large number of ribosomes. Ribosomes can be found in two locations. Bound ribosomes are those found attached to the endoplasmic reticulum (ER), and free ribosomes are those found in the cytoplasm. The two types are interchangeable and have identical structures, although they have slightly different roles.

Endoplasmic Reticulum

The ER is a membranous organelle found attached to the nuclear membrane and consists of two continuous parts. Through an electron microscope, it is clear that part of the membranous system is covered with ribosomes. This section of the ER is referred to as **rough ER,** and it is responsible for protein synthesis and membrane production. The other section of the ER lacks ribosomes and is referred to as **smooth ER.** It functions in the detoxification and metabolism of multiple molecules.

Golgi Apparatus

Inside the cell is a packaging, processing, and shipping organelle that is called the **Golgi apparatus.** The Golgi apparatus transports proteins from the ER throughout the cell.

Lysosomes

Intracellular digestion takes place in lysosomes. Packed with hydrolytic enzymes, the lysosomes can hydrolyze proteins, fats, sugars, and nucleic acids. Lysosomes normally contain an acidic environment (around pH 4.5).

Vacuoles

Vacuoles are membrane-enclosed structures that have various functions, depending on cell type. Many cells, through a process called **phagocytosis,** uptake food through the cell membrane, creating a food vacuole. Plant cells have a central vacuole that functions as storage, waste disposal, protection, and hydrolysis.

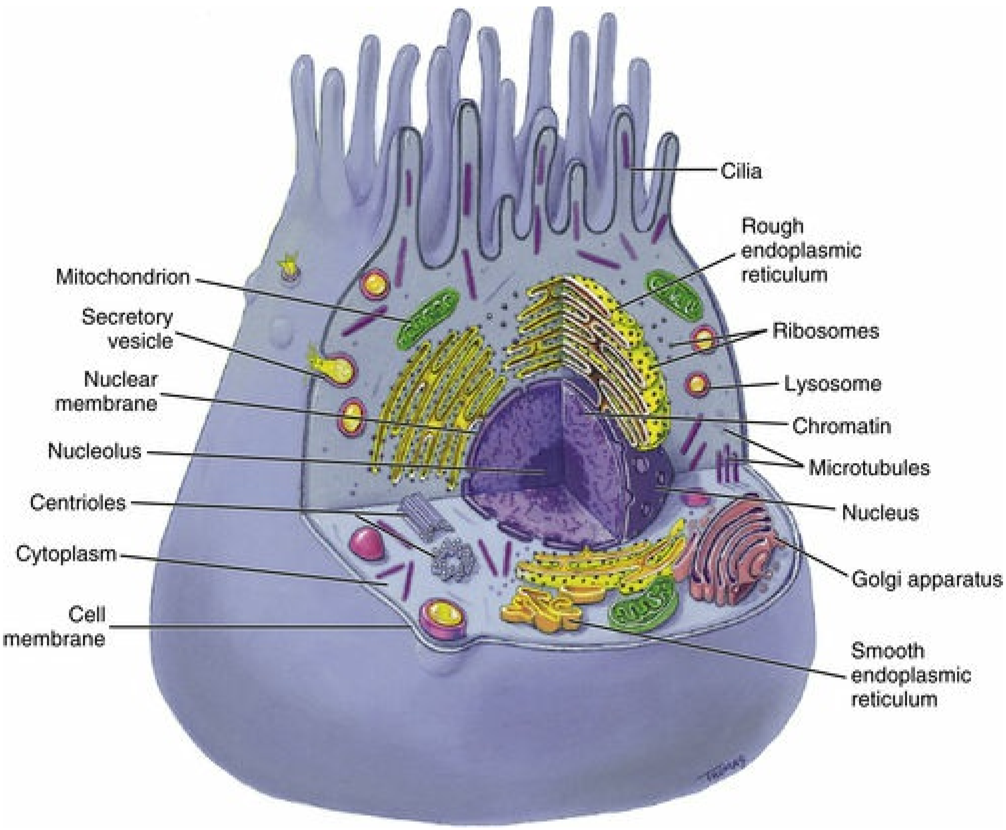

FIGURE 5-3 Generalized cell. (From Applegate: *The anatomy and physiology learning system,* ed 4, St Louis, 2011, Saunders.)

Mitochondria and Chloroplasts

There are two distinct organelles that produce cell energy: the mitochondrion and the chloroplast. Mitochondria are found in most eukaryotic cells and are the site of cellular respiration. Chloroplasts are found in plants and are the site of photosynthesis.

Cellular Membrane

The cellular membrane is the most important component of the cell, contributing to protection, communication, and the passage of substances into and out of the cell. The cell membrane itself consists of a bilayer of phospholipids with proteins, cholesterol, and glycoproteins peppered throughout. Because phospholipids are amphipathic molecules, this bilayer creates a hydrophobic region between the two layers of lipids, making it selectively permeable. Many of the proteins, which pass completely through the membrane, act as transport highways for molecular movement into and out of the cell. Figure 5-4 illustrates the structure of the cellular membrane.

Cellular Respiration

There are two catabolic pathways that lead to cellular energy production. As a simple combustion reaction, cellular respiration produces far more energy than does its anaerobic counterpart, fermentation.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

This balanced equation is the simplified chemistry behind respiration. The process itself actually occurs in a series of three complex steps that are simplified for our purposes.

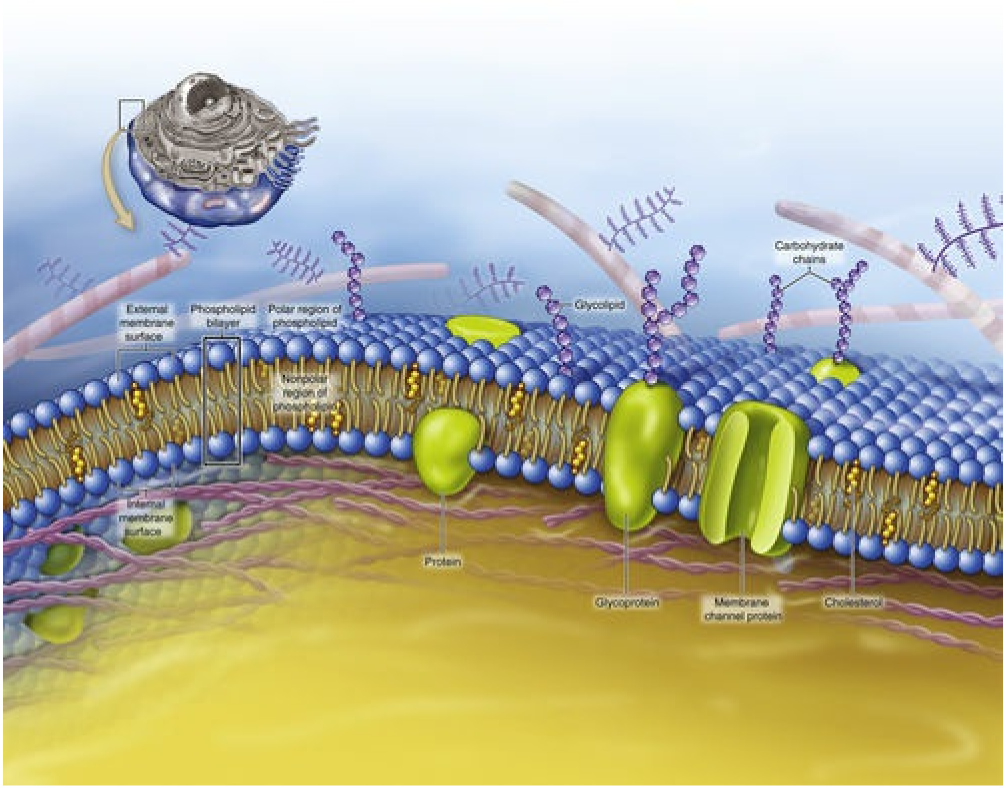

FIGURE 5-4 The plasma membrane is made of a bilayer of phospholipid molecules arranged with their nonpolar "tails" pointing toward each other. Cholesterol molecules help stabilize the flexible bilayer structure to prevent breakage. Protein molecules and protein-hybrid molecules may be found on the outer or inner surface of the bilayer—or extending all the way through the membrane. (From Patton KT, Thibodeau GA: *Anatomy and physiology*, ed 9, St Louis, 2016, Mosby.)

There is one molecule that is used as the energy currency of the cell: adenosine triphosphate (ATP). Another compound that acts as a reducing agent and is a vehicle of stored energy is reduced nicotinamide adenine dinucleotide

(NADH). This molecule is used as a precursor to produce greater amounts of ATP in the final steps of respiration.

The first step in the metabolism of food to cellular energy is the conversion of glucose to pyruvate in a process called **glycolysis.** It takes place in the cytosol of the cell and produces two molecules of ATP, two molecules of pyruvate, and two molecules of NADH.

In step two, the pyruvate is transported into a mitochondrion and used in the first of a series of reactions called the **citric acid cycle**, (also called the Krebs cycle). This cycle takes place in the matrix of the mitochondria, and for a single consumed glucose molecule, two ATP molecules, six molecules of carbon dioxide, and six NADH molecules are produced.

The third step begins with the oxidation of the NADH molecules to produce oxygen and finally to produce water in a series of steps called the **electron transport chain.** The energy harvest here is remarkable. For every glucose molecule, 28 to 32 ATP molecules can be produced.

This conversion results in overall ATP production numbers of 32 to 36 ATP molecules for every glucose molecule consumed. For a summary of cellular respiration, see Figure 5-5.

Photosynthesis

In the previous section the harvesting of energy by the cell was discussed. But where did that energy originate? It began with a glucose molecule and resulted in a large production of energy in the form of ATP. A precursor to the glucose molecule is produced in a process called **photosynthesis.**

The chemical reaction representing this process is simply the reverse of cellular respiration.

$$6CO_2 + 6H_2O + \text{Light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$

The only notable difference is the addition of light energy on the reactant side of the equation. Just as glucose is used to produce energy, so too must energy be used to produce glucose.

Photosynthesis is not as simple a process as it looks from the chemical equation. In fact, it consists of two different stages: the light reactions and the Calvin cycle. The light reactions are those that convert solar energy to chemical energy. The cell accomplishes the production of ATP by absorbing light and using that energy to split a water molecule and transfer the electron, thus creating nicotinamide adenine dinucleotide phosphate (NADPH) and producing ATP. These molecules are then used in the Calvin cycle to produce sugar.

The sugar produced is polymerized and stored as a polymer of glucose. These sugars are consumed by organisms or by the plant itself to produce energy by cellular respiration.

HESI Hint

When attempting to understand cell respiration and photosynthesis, keep in mind that these processes are cyclical. In other words, the raw materials for one process are the products of the other process. The raw materials for cellular respiration are glucose and oxygen, whereas the products of cell respiration are water, carbon dioxide, and ATP. Plants and other autotrophs will utilize the products of cell respiration (water, carbon dioxide) in the process of photosynthesis. The products of photosynthesis (oxygen, glucose) become the raw materials of cell respiration.

Cellular Reproduction

Cells reproduce by three different processes, all of which fall into two categories: sexual and asexual reproduction.

Asexual Reproduction

There are two types of asexual reproduction. The first involves bacterial cells and is referred to as **binary fission.** In this process, the chromosome binds to the plasma membrane, where it replicates. Then as the cell grows, it pinches in two, producing two identical cells (Figure 5-6).

Another type of asexual reproduction is called **mitosis.** This process of cell division occurs in five stages before pinching in two in a process called **cytokinesis.** The five stages are prophase, prometaphase, metaphase, anaphase, and telophase.

During prophase, the chromosomes are visibly separate, and each duplicated chromosome has two noticeable sister chromatids. In prometaphase, the nuclear envelope begins to disappear, and the chromosomes begin to attach to the spindle that is forming along the axis of the cell. Metaphase follows, with all the chromosomes aligning along what is called the **metaphase plate,** or the center of the cell. Anaphase begins when chromosomes start to separate. In this phase, the chromatids are considered separate chromosomes. The final phase is telophase. Here, chromosomes gather on either side of the now separating cell. This is the end of mitosis.

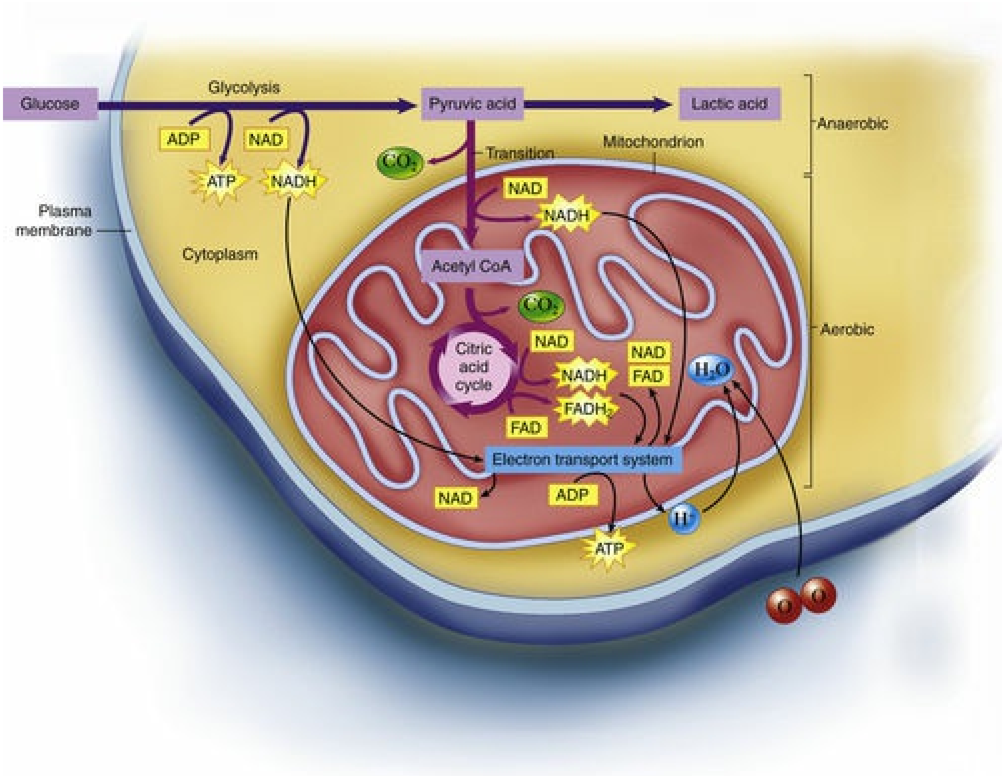

FIGURE 5-5 Summary of cellular respiration. This simplified outline of cellular respiration represents one of the most important catabolic pathways in the cell. Note that one phase *(glycolysis)* occurs in the cytosol but that the two remaining phases (*citric acid cycle* and *electron transport system*) occur within a mitochondrion. Note also the divergence of the anaerobic and aerobic pathways of cellular respiration. *ADP*, Adenosine diphosphate; *ATP*, adenosine triphosphate; *CoA*, coenzyme A; *FAD*, flavin adenine dinucleotide; *$FADH_2$*, form of flavin adenine dinucleotide; *NAD*, nicotinamide adenine dinucleotide; *NADH*, form of nicotinamide adenine dinucleotide. (From Patton KT, Thibodeau GA: *Anatomy and physiology*, ed 9, St Louis, 2016, Mosby.)

The second process associated with cell division is cytokinesis. During this phase, which is separate from the phases of mitosis, the cell pinches in two, forming two separate identical cells. A summary of mitosis is illustrated in Figure 5-7.

Sexual Reproduction

Sexual reproduction is different from asexual reproduction. In asexual reproduction, the offspring originates from a single cell, yielding all cells produced to be identical. In sexual reproduction, two cells contribute genetic material, resulting in significantly greater variation. These two cells find and fertilize each other randomly, making it virtually impossible for cells to be alike.

The process that determines how reproductive cells divide in a sexually reproducing organism is called **meiosis.** Meiosis consists of two distinct stages, meiosis I and meiosis II, resulting in four daughter cells (Figure 5-8). Each of these daughter cells contains half as many chromosomes as the parent. Preceding these events is a period called **interphase.** It is during interphase that

the chromosomes are duplicated and the cell prepares for division.

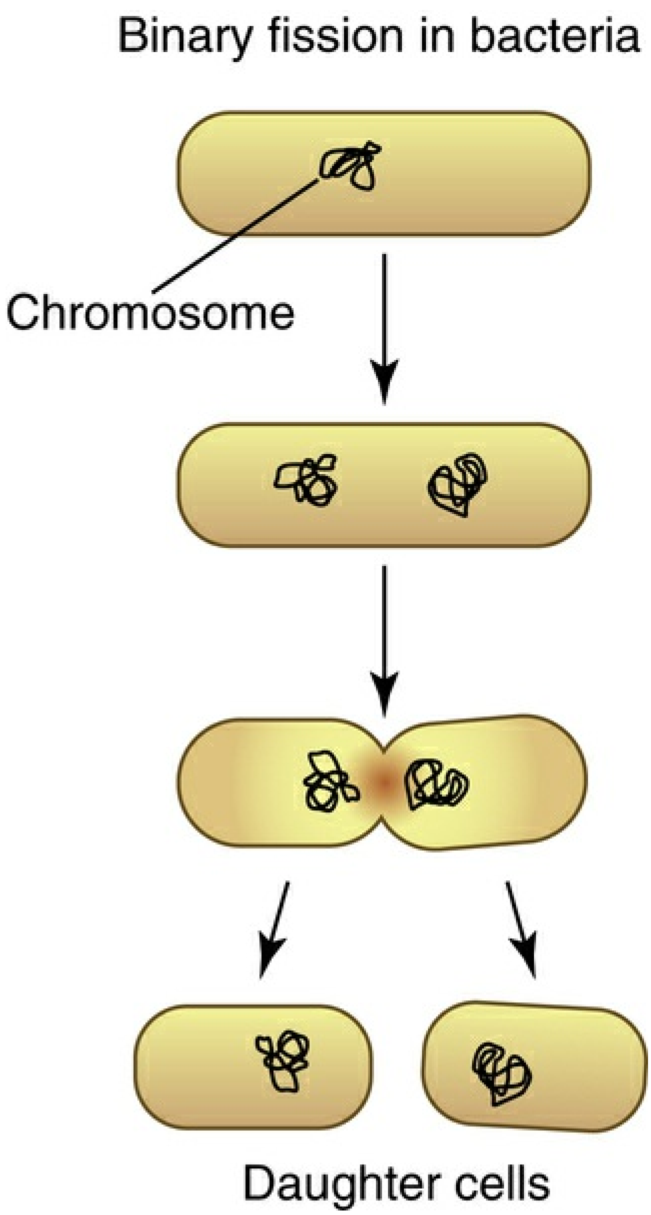

FIGURE 5-6 Binary fission. A single cell separates into two identical daughter cells, each with an identical copy of parent DNA. (Redrawn from VanMeter K, et al: *Microbiology for the healthcare professional,* St. Louis, 2010, Mosby.)

HESI Hint

Meiosis versus Mitosis

To illustrate the need for a reduction division (meiosis) in sex cell production, calculate the chromosome numbers that would result if sperm and egg cells were produced by mitosis. If both sperm and eggs were the

result of mitosis, their chromosome number would be 46, not 23. At fertilization, the chromosome number of the zygote would be 92, and the gametes produced by such an individual would also have 92 chromosomes. Of course, a zygote resulting from the fertilization of gametes containing 92 chromosomes would have a chromosome number of 184. The need to produce gametes by meiotic and not mitotic division soon becomes obvious.

The first stage of meiosis consists of four phases: prophase I, metaphase I, anaphase I, and telophase I and cytokinesis. The significant differences between meiosis and mitosis occur in prophase I. During this phase, nonsister chromatids of homologous chromosomes cross at numerous locations. Small sections of DNA are transferred between these chromosomes, resulting in increased genetic variation. The remaining three phases are the same as those in mitosis, with the exception that the chromosome pairs separate, not the chromosomes themselves.

After the first cytokinesis, meiosis two begins. Here, all four stages, identical to those of mitosis, occur. The resulting four cells have half as many chromosomes as the parent cell.

Genetics

Using garden peas, Gregor Mendel discovered the basic principles of genetics. By careful experimentation, he was able to determine that the observable traits in peas were passed from one generation to the next.

From Mendel's studies, scientists have found that for every trait expressed in a sexually reproducing organism, there are at least two alternative versions of a gene, called **alleles.** For simple traits, the versions can be one of two types: dominant or recessive. If both of the alleles are the same type, the organism is said to be **homozygous** for that trait. If they are different types, the organism is said to be **heterozygous.**

HESI Hint

If an allele is dominant for a particular trait, the letter chosen to represent that allele is capitalized. If the allele is recessive, then the letter is lowercased. If a dominant allele is present, then the phenotype expressed will be the dominant. The only way a recessive trait will be expressed is if both alleles are recessive.

By use of a device called a **Punnett square,** it is possible to predict genotype (the combination of alleles) and phenotype (what traits will be expressed) of the offspring of sexual reproduction. Alleles are placed one per column for one gene and one per row for the other gene. In the example in Figure 5-9, a homozygous dominant is crossed with a heterozygous organism for the same trait. Note that all progeny will express dominance for this trait. In the example in Figure 5-10, three of the possible combinations will be dominant, and one will be recessive for this trait.

The Punnett square can be used to cross any number of different traits simultaneously. With these data, a probability of phenotypes that will be produced can be determined. However, the more traits desired, the more complex the cross.

Not all genes express themselves according to these simple rules, but they are the basis for all genetic understanding. There are many other methods of genetic expression. A few of these include multiple alleles, pleiotropy, epistasis, and polygenic inheritance.

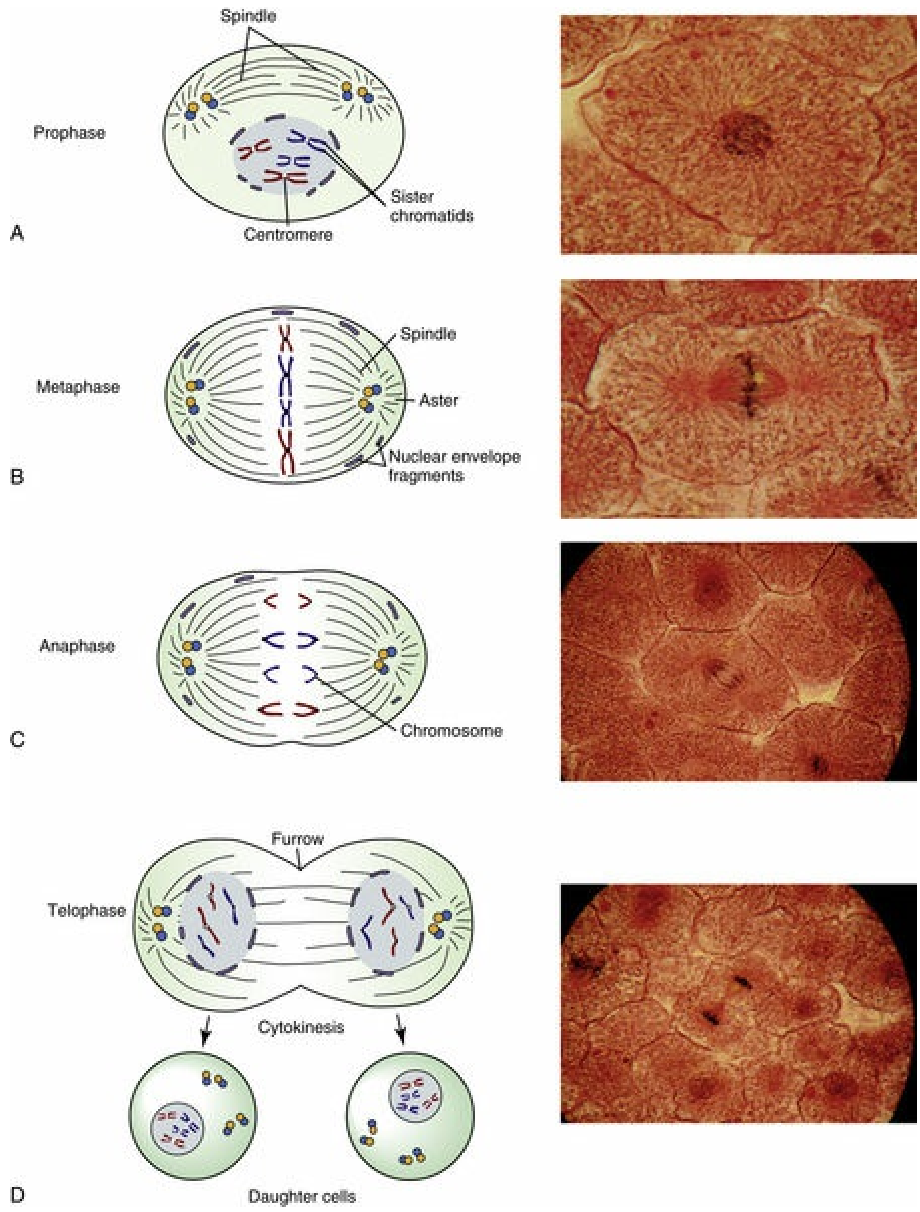

FIGURE 5-7 Mitosis. **A,** Prophase. **B,** Metaphase. **C,** Anaphase. **D,** Telophase. (Redrawn from VanMeter K, et al: *Microbiology for the healthcare professional,* St. Louis, 2010, Mosby.)

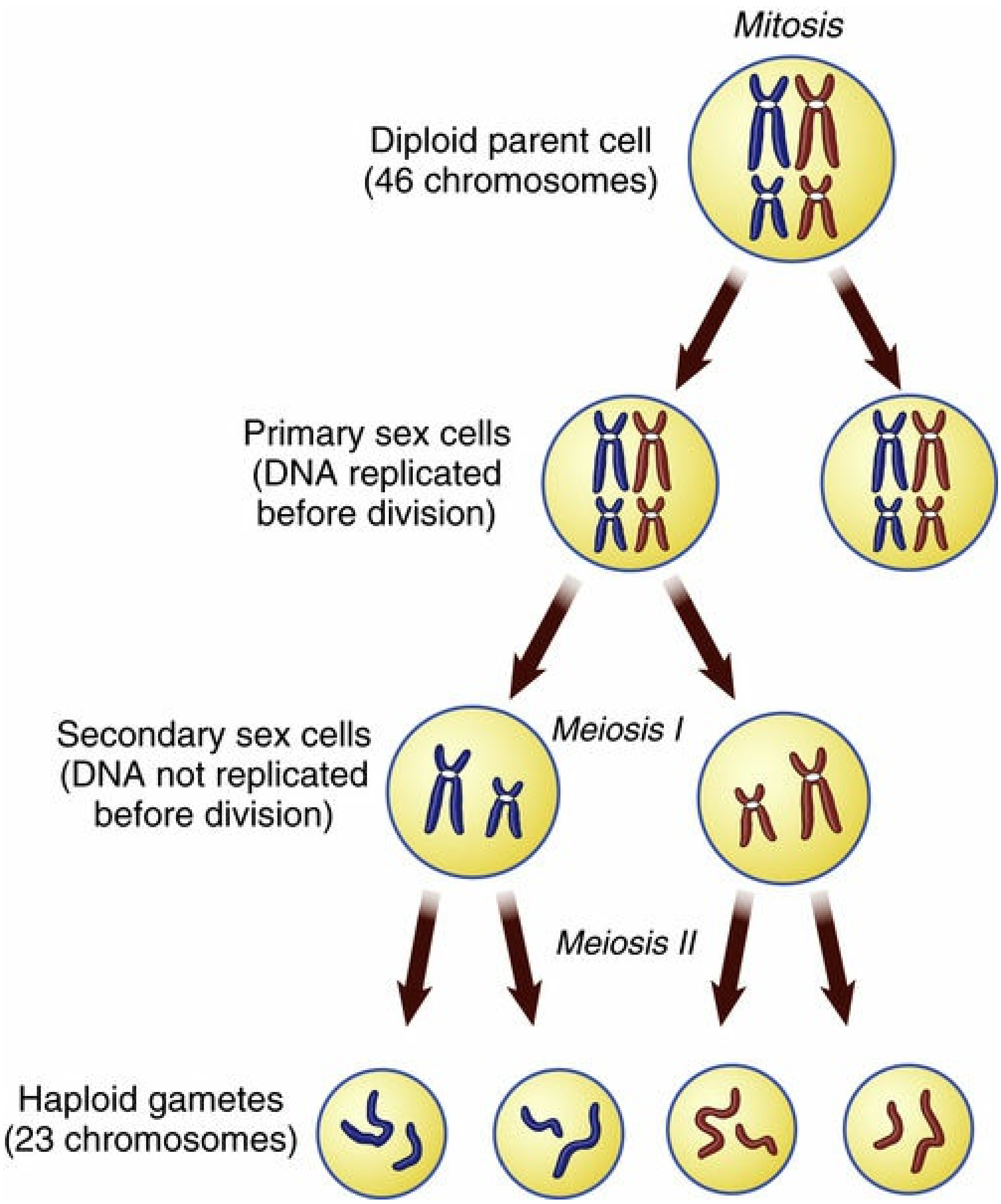

FIGURE 5-8 Meiosis. Meiotic cell division takes place in two steps: *meiosis I* and *meiosis II.* Meiosis is called *reduction division* because the number of chromosomes is reduced by half (from the diploid number to the haploid number). (From Patton KT, Thibodeau GA: *Anatomy and physiology,* ed 9, St Louis, 2016, Mosby.)

	R	R
R	RR	RR
r	Rr	Rr

FIGURE 5-9 Punnett square depicting the cross between a homozygous dominant and a heterozygous organism.

	R	r
R	RR	Rr
r	Rr	rr

FIGURE 5-10 Punnett square depicting three possible dominant combinations.

Because genetics is the study of heredity, many human disorders can be detected by studying a person's chromosomes or by creating a pedigree. A pedigree is a family tree that traces the occurrence of a certain trait through

several generations. A pedigree is useful in understanding the genetic past as well as the possible future.

DNA

DNA is the genetic material of a cell and is the vehicle of inheritance. In 1953, Watson and Crick described the structure of DNA. They described a double helical structure that contains the four nitrogenous bases adenine, thymine, guanine, and cytosine.

Each base forms hydrogen bonds with another base on the complementary strand. The bases have a specific bonding pattern. Adenine bonds with thymine, and guanine bonds with cytosine. Because of this method of bonding, the strands can be replicated, producing identical strands of DNA. During replication, the strands are separated. Then, with the help of several enzymes, new complementary strands to each of the two original strands are created. This produces two new double-stranded segments of DNA identical to the original (Figure 5-11).

Each gene along a strand of DNA is a template for protein synthesis. This production begins with a process called **transcription.** In this process, an RNA strand, complementary to the original strand of DNA, is produced. The piece of genetic material produced is called **messenger RNA (mRNA).** The RNA strand has nitrogenous bases identical to those in DNA with the exception of uracil, which is substituted for thymine.

mRNA functions as a messenger from the original DNA helix in the nucleus to the ribosomes in the cytosol or on the rough ER. Here, the ribosome acts as the site of translation. The mRNA slides through the ribosome. Every group of three bases along the stretch of RNA is called a **codon,** and each of these codes for a specific amino acid. The anticodon is located on a unit called **transfer RNA (tRNA),** which carries a specific amino acid. It binds to the ribosome when its codon is sliding through the ribosome. Remember that a protein is a polymer of amino acids, and multiple tRNA molecules bind in order and are released by the ribosome. Each amino acid is bonded together and released by the preceding tRNA molecule, creating an elongated chain of amino acids. Eventually the chain is ended at what is called a **stop codon.** At this point, the chain is released into the cytoplasm, and the protein folds onto itself and forms its complete conformation.

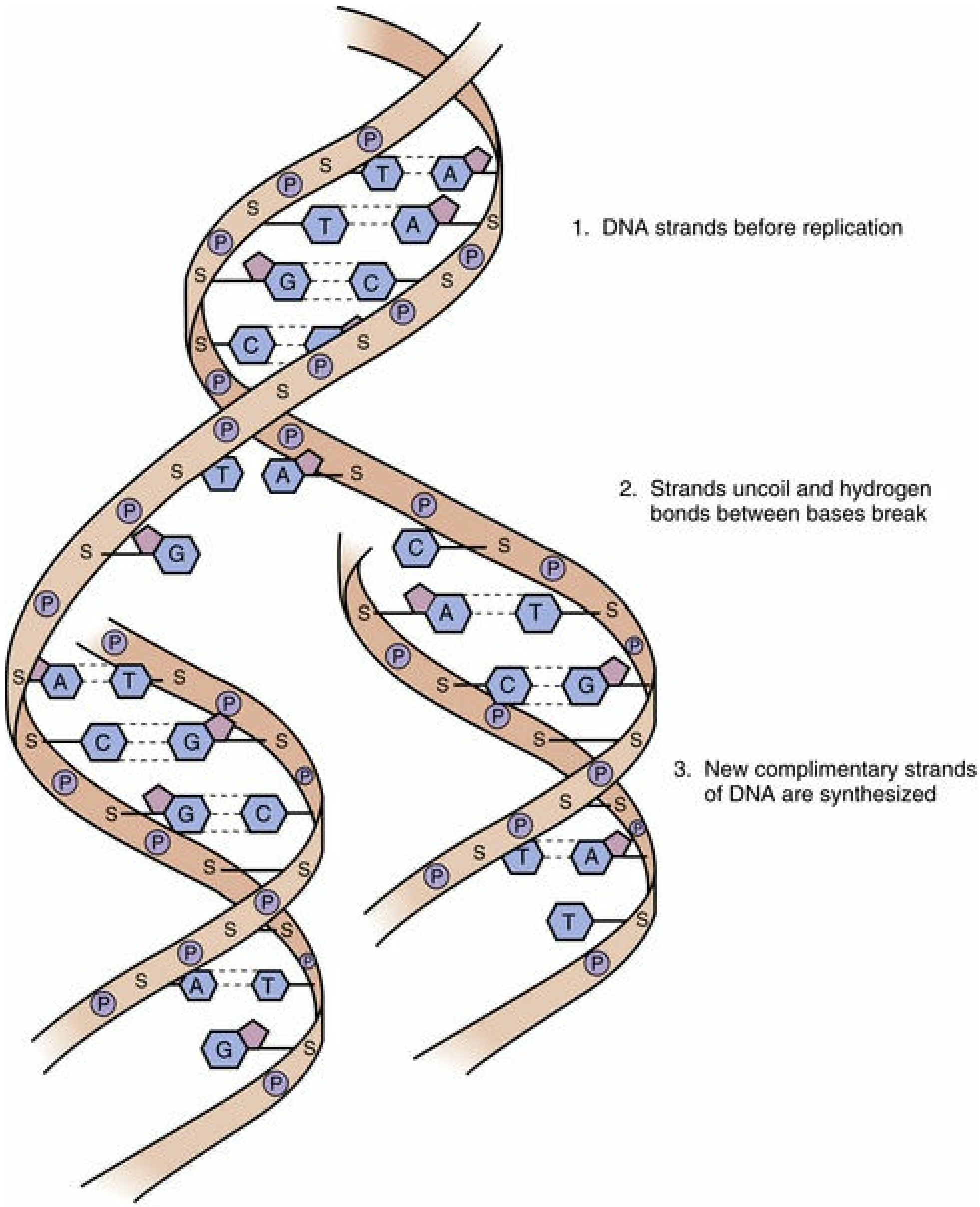

FIGURE 5-11 DNA replication. When a DNA molecule makes a copy of itself, it "unzips" to expose its nucleotide bases. Through the mechanism of obligatory base pairing, coordinated by the enzyme *DNA polymerase,* new DNA nucleotides bind to the exposed bases. This forms a new "other half" to each half of the original molecule. After all the bases have new nucleotides bound to them, two identical DNA molecules will be ready for distribution to the two daughter cells. (From Applegate: *The anatomy and physiology learning system,* ed 4, St Louis, 2011, Saunders.)

By dictating what is produced in translation through transcription, the DNA in the nucleus has control over everything taking place in the cell. The proteins that are produced will perform all the different cellular functions required for the cell's survival. The synthesis of proteins is summarized in Figure 5-12.

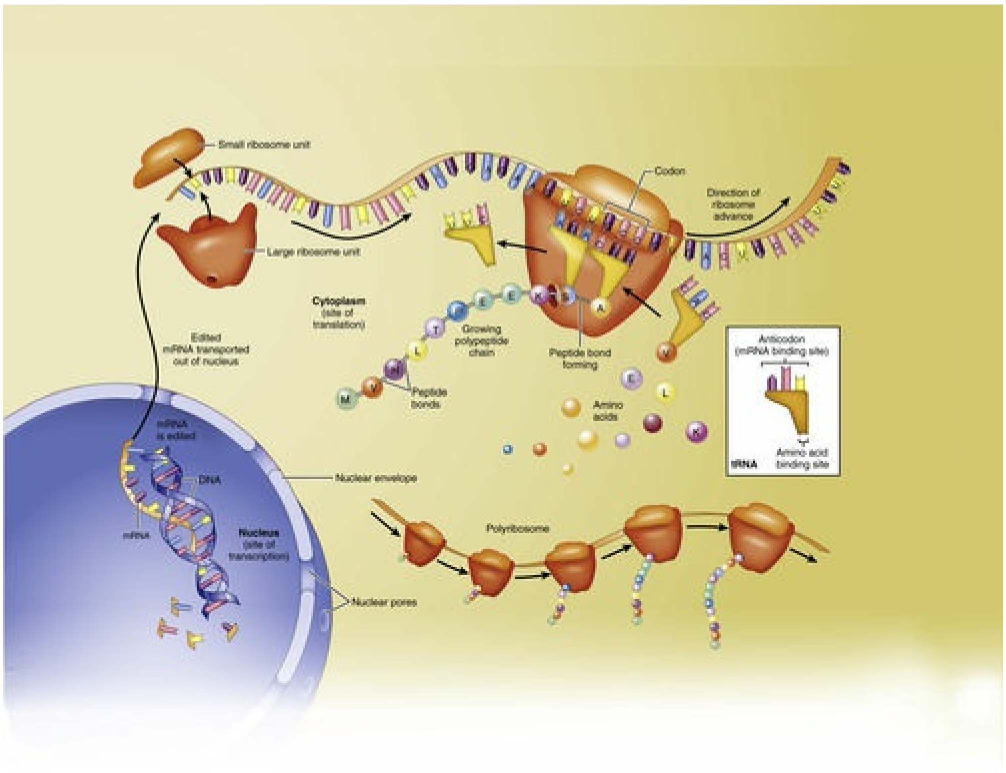

FIGURE 5-12 Protein synthesis begins with *transcription,* a process in which a messenger RNA (mRNA) molecule forms along one gene sequence of a DNA molecule within the cell's nucleus. As it is formed, the mRNA molecule separates from the DNA molecule, is edited, and leaves the nucleus through the large nuclear pores. Outside the nucleus, ribosome subunits attach to the beginning of the mRNA molecule and begin the process of *translation.* In translation, transfer RNA (tRNA) molecules bring specific amino acids—encoded by each mRNA codon—into place at the ribosome site. As the amino acids are brought into the proper sequence, they are joined together by peptide bonds to form long strands called *polypeptides.* Several polypeptide chains may be needed to make a complete protein molecule. (From Patton KT, Thibodeau GA: *Anatomy and physiology,* ed 9, St Louis, 2016, Mosby.)

Review Questions

1. Within the biologic hierarchic system of organization, which of the following is *least* inclusive?
   A. Phylum
   B. Order
   C. Kingdom
   D. Species
2. In the scientific process, which of the following is a statement or explanation of certain events or happenings?
   A. Hypothesis
   B. Observation
   C. Experiment
   D. Conclusion
3. Why is polarity the most important characteristic of water?
   A. The results of the polarity are hydrogen bonding, a high specific heat value, and its versatile solvent properties.
   B. The results of the polarity are covalent bonding, a low specific heat value, and its versatile solvent properties.
   C. The results of the polarity are ionic bonding, a high specific heat value, and its versatile solvent properties.
   D. The results of the polarity are hydrogen bonding, a low specific heat value, and its versatile solvent properties.
4. Athletes are often concerned with the question of what they need in their diets to increase muscle mass and strength. What biologic molecule would you recommend that would accomplish this?
   A. Carbohydrates
   B. Proteins
   C. Lipids
   D. Nucleic acids
5. Which organelle would you expect to be present in a cell responsible for detoxifying multiple molecules?
   A. Rough endoplasmic reticulum
   B. Smooth endoplasmic reticulum
   C. Lysosome
   D. Golgi apparatus
6. A cell from heart muscle would more than likely contain an unusually high proportion of:

A. Lysosomes

B. Mitochondria

C. mRNA

D. Ribosomes

7. The sum of all chemical reactions that occur in an organism is:

A. Product

B. Respiration

C. Metabolism

D. Synthesis

8. A cell that does not contain membrane-bound organelles or a defined nucleus would be classified as:

A. Eukaryotic

B. Embryonic

C. Prokaryotic

D. Symbiotic

9. The two catabolic pathways that lead to cellular energy production are:

A. Fermentation and protein synthesis

B. Cellular respiration and glycolysis

C. Fermentation and glycolysis

D. Cellular respiration and fermentation

10. Which part of cellular respiration produces the greatest amount of ATP?

A. Electron transport chain

B. Glycolysis

C. Citric acid cycle

D. Fermentation

11. When plants do not receive enough water, their photosynthetic rate drops. This is because:

A. Water is a raw material for the light reactions in photosynthesis.

B. Carbon dioxide is not available.

C. Water provides the carbon atoms used to make sugar.

D. Not enough oxygen is produced to keep fermentation running.

12. How does asexual reproduction differ from sexual reproduction?

A. Asexual reproduction results in all cells being identical to the original cell; sexual reproduction results in half of the cells being identical to the original cell.

B. Asexual reproduction results in two cells that contribute genetic material to daughter cells, resulting in significantly greater variation.

C. Sexual reproduction involves two cells that contribute genetic material to

daughter cells, resulting in significantly greater variation.

D. Sexual reproduction involves one cell that yields all cells produced to be identical.

13. Why is it important for cells to undergo mitosis?

A. Mitosis allows for reproduction with male and female gametes.

B. Mitosis increases variation within the species.

C. Mitosis produces cells that are different from the parent cell.

D. Mitosis produces cells for growth and repair of body tissue.

14. 72 Chromosomes undergo meiosis. How many chromosomes will be in each gamete?

A. 18

B. 36

C. 72

D. 144

15. Which of the following shows how information is transformed to make a protein?

A. DNA-RNA-protein

B. Gene-chromosome-protein

C. ATP-amino acid-protein

D. RNA-DNA-protein

Answers to Review Questions

1. D
2. A
3. A
4. B
5. B
6. B
7. C
8. C
9. D
10. A
11. A
12. C
13. D
14. B
15. A

Chemistry

CHAPTER OUTLINE

KEY TERMS

Acid
Atom
Atomic Mass
Atomic Number
Base
Basic Unit of Measure
Biochemistry
Catalysts
Celsius
Chemical Equations
Combustion
Compound

Covalent Bond
Decomposition
Deoxyribose
Double Replacement
Electron
Electron Clouds
Equilibrium
Fahrenheit
Groups
Ionic Bond
Isotope
Kelvin
Mathematical Sign
Mole
Neutron
Nucleus
Orbit
Periodic Table
Periods
pH
Prefix
Products
Proton
Reactants
Ribose
Scientific Notation
Significand
Single Replacement
Solute
Solution
Solvent
Synthesis

Chemistry is a part of our everyday lives. Almost three quarters of the objective

information in a client's medical record consists of laboratory data derived from chemical analytical testing. Laboratory tests and chemical analysis play an important role in the detection, identification, and management of most diseases. The client's evaluation, diagnosis, treatment, care, and prognosis are, at least in part, based on the chemical information from laboratory tests that involve traditional technologies of chemistry. A sound, basic knowledge of chemistry enables the health care professional to reduce the risk of mishandled biologic samples and misdiagnosis and thereby deliver safer and higher quality care.

Chemistry is the study of matter and its properties. Everything in the universe is made or composed of different kinds of matter in one of its three states: solid, liquid, or gas. Matter is defined by its properties, and chemistry is a study of those properties and how those properties relate to one another. Chemistry is a very broad field of study and can be divided into many areas of specialization, such as physical or general chemistry, biochemistry, and organic and inorganic chemistry. This chapter reviews chemistry from the most basic of substances to very complex compounds.

Scientific Notation, the Metric System, and Temperature Scales

Scientific Notation

Scientific notation is the scientific system of writing numbers. Scientific notation is a method to write very big or very small numbers easily. Scientific notation is composed of three parts: a **mathematical sign** (+ or −), the **significand,** and the exponential, sometimes called the *logarithm.*

1. The mathematical sign designates whether the number is positive or negative.

HESI Hint

There is an understood (+) before a positive significand as there is in all positive numbers.

2. The significand is the base value of the number or the value of the number when all the values of ten are removed.
3. The exponential is a multiplier of the significand in powers of ten (Table 6-1). A positive exponential multiplies the significand by factors of ten. A negative exponential multiplies the significand by factors of one tenth (0.1).

HESI Hint

Some calculators or other devices may write the exponent as an "e" or "E" as in 3.2 e5 or 3.2 E5, called E notation, instead of 3.2×10^5, but it means the same.

Table 6-1

Exponentials*

10^9	1,000,000,000
10^6	1,000,000
10^3	1,000
10^2	100
10^1	10
10^0	1
10^{-2}	0.01
10^{-6}	0.000001
10^{-9}	0.000000001

* 1.0 is understood to be the significand with each of the above exponentials.

Example

Consider -9.0462×10^5, where the minus (−) sign makes this a negative number, 9.0462 is the significand or base value, and 10^5 is the exponential or multiplier of the significand in the power of ten. In the example above, -9.0462×10^5 equals $-9.0462 \times 10 \times 10 \times 10 \times 10 \times 10$ or −904,620.

Example

Consider 4.7×10^{-3}, where the absence of the (+) sign is understood as positive, 4.7 is the significand or base value, and 10^{-3} is the exponential or multiplier of the significand in the negative power of ten (as tenths). In the example above, 4.7×10^{-3} equals $(4.7 \times 0.1 \times 0.1 \times 0.1)$ or 0.0047.

HESI Hint

Move the decimal in the significand the number of places equal to the exponent of 10. When the exponent is positive, the decimal is moved to the right, and when the exponent is negative, the decimal is moved to the left.

HESI Hint

When writing a number between −1 and +1, always place a zero (0) to the left of the decimal. Write 0.62 and −0.39 (do not write .62 or −.39). This will avoid mistakes when reading the number and locating the decimal.

The Metric System of Measurement

The metric system is a method to measure weight, length, and volume. It is a simple, logical, and efficient measurement system that is the standard in health professions. The basic measurements of the metric system are grams, liters, and meters. A gram (g) is the basic measure of weight, a liter (L) is the basic measure of volume, and a meter (m) is the basic measure of distance.

Each metric measurement is composed of a metric prefix and a basic unit of measure. An example is "kilogram," where "kilo" is the **prefix** and "gram" is the **basic unit of measure.** The prefixes have the same meaning or value, regardless of which basic unit of measurement (grams, liters, or meters) is used. Prefixes are the quantifiers of the measurement units. All of the prefixes are based on multiples of ten. Any *one* of the prefixes can be combined with *one* of the basic units of measurement. Some examples are deciliter (dL), kilogram (kg), and millimeter (mm) (Table 6-2).

Table 6-2
The Prefixes

Prefix	Abbreviation	Means	Numerically
Tera	T-	10^{12}	1 trillion times
Giga	G-	10^9	1 billion times
Mega	M-	10^6	1 million times
kilo	k-	10^3	1 thousand times
hecto	h-	10^2	1 hundred times
deka	D-	10^1	10 times
deci	d-	10^{-1}	1 tenth of
centi	c-	10^{-2}	1 hundredth of
milli	m-	10^{-3}	1 thousandth of
micro	μ-	10^{-6}	1 millionth of
nano	n-	10^{-9}	1 billionth of
pico	p-	10^{-12}	1 trillionth of
femto	f-	10^{-15}	1 quadrillionth of

HESI Hint

Some comparisons may give more insight to sizes or amounts: A meter is a little more than 3 inches longer than a yard. A dime is a little less than 2 cm in diameter. A kilogram is about 2.2 lb. A liter is a little more than a quart.

Temperature Scales

The three most common temperature systems are **Fahrenheit, Celsius,** and **Kelvin.**

Fahrenheit (F) is a temperature measuring system used only in the United States, its territories, Belize, and Jamaica. It is rarely used for any scientific measurements except for body temperature (see Table 6-3). It has the following characteristics:

a. Zero degrees (0° F) is the freezing point of sea water or heavy brine at sea level.
b. 32° F is the freezing point of pure water at sea level.
c. 212° F is the boiling point of pure water at sea level.

Table 6-3

Important Temperatures in Fahrenheit and Celsius

Condition	Examples of Celsius (C) and Fahrenheit (F) Temperatures	
Freezing water	0° C	32° F
Normal body temperature	37° C	98.6° F
Boiling water	100° C	212° F

d. Most people have a body temperature of 98.6° F.

Celsius (sometimes called Centigrade) is a temperature system used in the rest of the world and by the scientific community. It has the following characteristics:

a. Zero degrees (0° C) is the freezing point of pure water at sea level.
b. 100° C is the boiling point of pure water at sea level.
c. Most people have a body temperature of 37° C.

Kelvin (K) is used only in the scientific community. Kelvin has the following characteristics:

a. Zero degrees (0K) is −273.15° C and is thought to be the lowest temperature achievable or absolute zero (0).
b. The freezing point of water is 273K.
c. The boiling point of water is 373K.
d. Most people have a body temperature of 310K, but this is never used.

Atomic Structure and the Periodic Table

Atomic Structure

The basic building block of all molecules is the atom. An **atom's** physical structure is that of a **nucleus** and **orbits,** sometimes called **electron clouds.** The nucleus is at the center of the atom and is composed of **protons** and **neutrons.** At the outermost part of the atom are the orbits of the **electrons,** which spin around the nucleus at fantastic speeds, forming electron clouds. The speed of the electrons is so great that, in essence, they occupy the space around the nucleus as a cloud rather than as discrete individual locations. The electrons orbit the nucleus at various energy levels called *shells* or *orbits,* almost like the layers of an onion. As each orbital is filled to capacity, atoms begin adding electrons to the next orbit. An atom is most stable when its outermost orbit is full. However, most of the volume of an atom is empty space. See Figure 6-1 for examples of atoms.

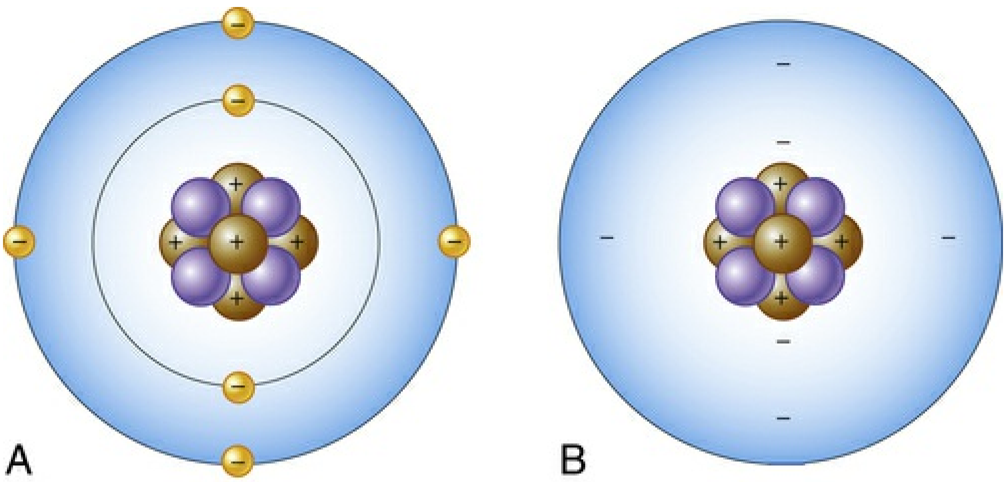

FIGURE 6-1 Models of the atom. The nucleus consists of protons (+) and neutrons at the core. Electrons inhabit outer regions called electron shells or energy levels **(A)** or **(B)** clouds. (From Patton KT, Thibodeau GA: *Anatomy and physiology,* ed 9, St. Louis, 2016, Mosby.)

Protons have a positive electrical charge, electrons have a negative charge, and neutrons have no charge at all. Ground state atoms tend to have equal numbers of protons and electrons, making them electrically neutral. When an atom is electrically charged, it is called an *ion* or it is said to be in an ionic state. This usually occurs when it is in a solution or in the form of a chemical compound. An atom in an ionic state will have lost electrons, resulting in a net positive charge, or will have gained electrons, resulting in a net negative charge. The atom is called a *cation* if it has a positive charge and an *anion* if it has a negative charge.

The Periodic Table

Matter is defined by its properties. It can also be stated that the properties of matter come from the properties of its composite elements, and the periodic table organizes the elements based on their structure and thus helps predict the properties of each of the elements (Figure 6-2).

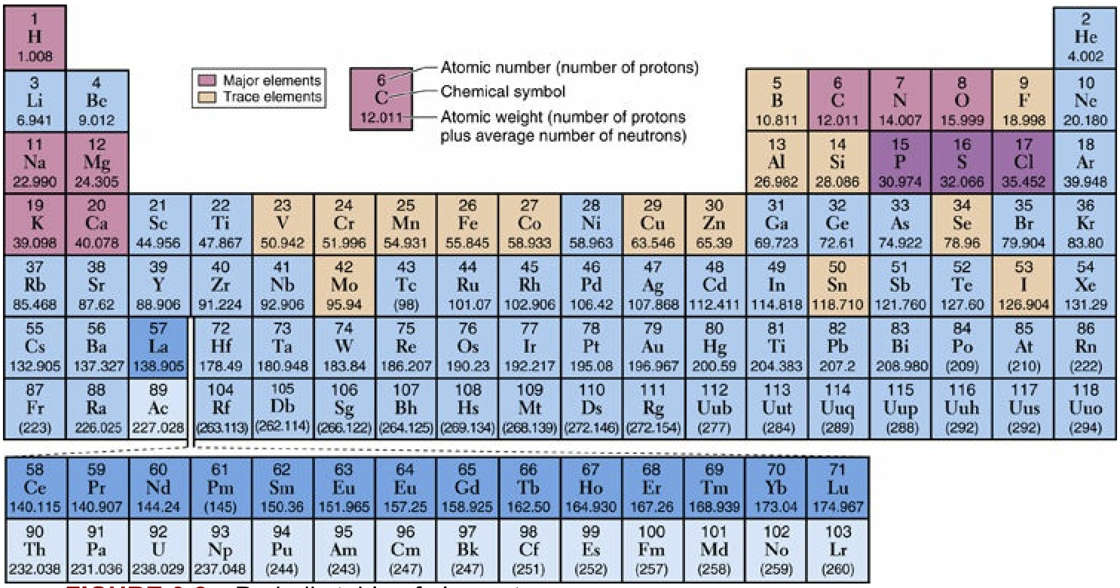

FIGURE 6-2 Periodic table of elements. (From Patton KT, Thibodeau GA: *Anatomy and physiology*, ed 9, St. Louis, 2016, Mosby.)

The **periodic table** is made up of a series of rows called **periods** (hence the name periodic table) and columns called **groups.** It is, at its simplest, a table of the known elements arranged according to their properties. The periodic table makes it possible to predict, for example, the charge of an atom or element, when it exists as an ion, by its location in the table. Group IA has a plus one (+1) charge, group IIA has a positive two (+2) charge, and group IIIA has a positive 3 (+3) charge. Group IVA can have either a positive four (+4) or a negative four (−4) charge. The negative charges are as follows: group VA has a negative three (−3) charge, group VIA has a negative two (−2) charge, and group VIIA has a negative one (−1) charge. Group VIIIA, called the noble gases, has no charge when in solution; it remains neutral in nearly all situations. Another property that can be generally deduced by the periodic chart is the number of electrons in the outer electron shell or cloud. Group IA will have one (1) electron in its outer shell. Group IIA will have two (2) electrons in its outer shell. Group IIIA will have three (3), Group IVA will have four (4), and on through all of the A groups. The Groups 3 IIIB through 12 IIB are called *transition metals* and are not as straightforward to predict because of some exceptions to the rules.

HESI Hint

An important principle to remember is that the properties of each element can be predicted based on its location in the periodic chart.

Atomic Number and Atomic Mass

Two important numbers or properties of atoms that can be obtained from the periodic table are the atomic number and the atomic mass.

The **atomic number** is the number of protons in the nucleus, and it defines an atom as a particular element. For instance, any atom that has eleven (11) protons, no matter how many neutrons or electrons, is sodium (Na). If an atom has six (6) protons, it is carbon (C). The atomic number is located at the top of each of the squares in a periodic table. It is always a whole number.

The **atomic mass** of an atom is the *average* mass of each of that element's **isotopes.** Isotopes are different kinds of the same atom that vary in weight. Protons and neutrons each have approximately the same mass or weight, which makes up nearly all of the atom's total mass. The atomic mass is the number at the bottom of each of the squares in the periodic table, and it is usually a decimal number. For a given element, the number of protons remains the same, whereas the number of neutrons varies to make the different isotopes. The most common isotope of an atom, generally, has the same number of protons and neutrons in its nucleus. The element Carbon 12 (^{12}C), the most common carbon, has six (6) protons and six (6) neutrons. The isotope used for "carbon dating" is Carbon 14 (^{14}C), which has six (6) protons and eight (8) neutrons.

Chemical Equations

An element or atom is the simplest form of matter that can naturally exist in nature. It can exist as pure substance or in combination with other elements. When they exist in combination with other elements, the combination is called a **compound,** and they combine in whole number ratios. A part of an element does not naturally exist; at least one atom of the element is present in a chemical reaction. For instance, the elements sodium (Na) and chlorine (Cl) will combine perfectly as whole elements or atoms in a one-to-one ratio to make the compound table salt (NaCl).

Chemical equations are simply recipes. Ingredients, called **reactants,** react to produce desired end results or compounds, called **products.** Equations are written in the following manner:

$$\text{Reactants} \rightarrow \text{Products}$$

In any chemical reaction, an arrow between the reactants and the products is present. This arrow symbolizes the direction of the reaction. Some reactions move toward the product side as seen above, and some reactions will move toward the reactant side with an arrow pointing toward the reactants instead of the products.

$$\text{Reactants} \leftarrow \text{Products}$$

There are also reactions that will create both reactants and products at the same time.

$$\text{Reactants} \leftrightarrow \text{Products}$$

An example is the reaction of aqueous silver nitrate ($AgNO_3$) and aqueous potassium chloride (KCl) to produce solid silver chloride (AgCl) and potassium nitrate (KNO_3).

$$AgNO_3 + KCl \rightarrow AgCl + KNO_3$$

$$\text{Silver nitrate} + \text{Potassium chloride yields}$$

Silver chloride + Potassium nitrate

The law of conservation of mass states that mass cannot be created or destroyed during a chemical reaction. Therefore, once the reactants have been written and the products predicted, the equation must be balanced. The same number of each element must be represented on both sides of the equation. The above example has one silver atom, one nitrogen atom, three oxygen atoms, one potassium atom, and one chloride atom on each side of the equation. Therefore, nothing in the way of matter was created or destroyed; it was simply rearranged.

Reaction Rates, Equilibrium, and Reversibility

Chemical reactions generally proceed at a specific rate. Some reactions are fast, and some are slow. A chemical reaction may proceed to completion, but some reactions may stop before all of the reactants are used to make products. These reactions are said to be at **equilibrium.** Equilibrium is a state in which reactants are forming products at the same rate that products are forming reactants. A reaction at equilibrium can be said to be reversible. As the chemicals A and B react to create C and D, C and D react to make more A and B at the same rate.

$$A + B \leftrightarrow C + D$$

Through manipulation of the reaction by various means, shifts in equilibrium reversibility or the rate of the reaction can be controlled. There are basically four ways to increase the reaction rate: increase the temperature in the reaction, increase the surface area of the reactants, add a catalyst, or increase the concentrations of reactants.

Increasing the Temperature

Increasing the temperature causes the particles to have a greater kinetic energy, thereby causing them to move around faster, increasing their chances of contact and the energy with which they collide. Contact is when the chemical reactions occur.

Increasing the Surface Area

Increasing the surface area of the particles in the reaction gives the particles more opportunity to come into contact with one another. Wood shavings are an excellent example. One can increase the surface area of a log by cutting it into shavings or sawdust. Wood in the form of sawdust will burn or react much faster than a whole log.

Catalysts

A **catalyst** accelerates a reaction by reducing the activation energy or the amount of energy necessary for a reaction to occur. The catalyst is not used up in the reaction and can be collected at completion of the reaction. Various substances can be catalysts. Common examples include metals and proteins (protein catalysts are called enzymes).

Increasing the Concentration

Increasing the concentration of the reactants will cause more chance collisions between the reactants and produce more products. By analogy, if there are more cars on the road, there are likely to be more accidents or collisions. The more reactants there are, the faster and more often they will bump into each other and react or become products.

Solutions and Solution Concentrations

Solutions

A **solution** can be defined as a homogeneous mixture of two or more substances. In a solution, there is the **solute,** the part or parts that are being dissolved, and the **solvent,** the part that is doing the dissolving. Solutions can be a liquid in a liquid, a solid in a liquid, or a solid in a solid. The following are types of solutions.

Compounds: Mixtures of different elements to create a single matter.

Alloys: Solid solutions of metals to make a new one such as bronze, which is copper and tin, or steel, which is iron and carbon, and may contain, tungsten, chromium, and manganese.

Amalgams: A specific type of alloy in which a metal is dissolved in mercury.

Emulsions: Mixtures of matter that readily separate such as water and oil.

Concentration of Solutions—Percent Concentration

Concentration is expressed as weight per weight, as in grams per grams; weight per volume, as in grams per liters; or volume per volume, as in milliliters per liter. Percent concentration is the expression of concentrations as parts per 100 parts. Therefore, most concentrations of this type are expressed as milligrams (mg) per 100 milliliters (mL), which can also be written as mg/100mL or mg/dL. A concentration expression of milliliters (mL) per 100 milliliters (mL) can be written as mL/100mL or mL/dl.

Concentration of Solutions—Molar Concentration

Molarity, or molar concentration, is a more sophisticated way to express concentrations than percent. One of the most important concepts in chemistry is the “mole.” A **mole** is 6.02×10^{23} molecules of something. This number, 6.02×10^{23}, which is more than a trillion trillions, is known as *Avogadro’s number.* A one molar solution will contain 6.02×10^{23} representative molecules of a solute in a liter of solvent. Molar concentrations are written as mol/L. It is important to note that if one measured the atomic mass of any element in grams (g), he or she will have weighed out one mole or 6.02×10^{23} atoms of that element or compound.

Chemical Reactions

A chemical reaction involves making or changing chemical bonds between elements or compounds to create new chemical compounds with different chemical formulas and different chemical properties. There are five main types of chemical reactions: synthesis, decomposition, combustion, single replacement, and double replacement. When a reaction occurs, the product is generally a molecule. A molecule may have a subscript written after the chemical symbol as in O_2, which is oxygen.

Synthesis: In a **synthesis** reaction, two elements combine to form a product. An example is the formation of potassium chloride salt when the element potassium (K^+) combines with the element chloride (Cl^-) in a solution:

$$2K^+ + 2Cl^- \rightarrow 2KCl$$

Two potassium atoms + two chloride atoms yields 2 molecules of potassium chloride.

Decomposition: **Decomposition** is often described as the opposite of synthesis because it is the breaking of a compound into its component parts.

$$NaCl \rightarrow Na^+ + Cl^-$$

When placed in an aqueous solution, table salt (NaCl) decomposes or breaks apart into an ionic solution of sodium (Na^+) as a cation and chloride (Cl^-) as an anion.

Combustion: **Combustion** is a self-sustaining, exothermic (creates heat) chemical reaction where oxygen and a fuel compound such as a hydrocarbon react. In the combustion of hydrocarbon (gas or oil product), the products are carbon dioxide (CO_2) and water (H_2O). The combustion of ethane (C_2H_6) would look like this in a chemical equation, where (g) stands for gas:

$$2C_2H_6\ (g) + 7O_2\ (g) \rightarrow 4CO_2\ (g) + 6H_2O\ (g)$$

Single Replacement: Replacement reactions involve ionic compounds; whether or not the reaction will take place is based on the reactivity of the metals involved. **Single replacement** reactions consist of a more active metal reacting with an ionic compound containing a less active metal to produce a new compound. A good example is the reaction of copper (Cu) with aqueous silver nitrate ($AgNO_3$). The copper (Cu) and the silver (Ag) simply swap places.

This type of reaction is referred to as single replacement and is illustrated in the following equation, where (aq) stands for aqueous and (s) stands for solid:

$$Cu\ (s) + 2AgNO_3\ (aq) \rightarrow Cu(NO_3)_2\ (aq) + 2Ag\ (s)$$
$$\text{Copper} + \text{silver nitrate yields}$$
$$\text{copper nitrate} + \text{silver}$$

Double Replacement: **Double replacement** reactions involve two ionic compounds. The positive ion from one compound combines with the negative ion of the other compound. The result is two new ionic compounds that have "switched partners." The example of the reaction of silver nitrate ($AgNO_3$) and potassium chloride (KCl) is a good representation of double replacement:

$$AgNO_3 + KCl \rightarrow AgCl + KNO_3$$

$$\text{Silver nitrate} + \text{potassium chloride yields}$$

$$\text{silver chloride} + \text{potassium nitrate}$$

Chemical Bonding

Chemical bonding is the joining of one atom, element, or chemical to another. Some bonds are very weak, and some are nearly unbreakable. In many cases the type of bonding will be determined by the interplay of the electrons in the outer shell of the atom. There are two main types of chemical bonding: ionic and covalent.

Ionic Bonding: An **ionic bond** is an electrostatic attraction between two oppositely charged ions, or a cation and an anion. This type of bond is generally formed between a metal and a nonmetal. An excellent example of ionic bonding is salt. Since opposites attract, the positive cation will attract the negative anion and form an electrostatic bond. In this type of a bond the cation (sodium) *takes* one electron from the anion (chlorine), which makes the overall molecule electrically neutral. This *taking and giving* of an electron completes the outer electron orbits, making both substances very stable. Sodium (Na^+) needs one electron and Chlorine (Cl^-) has an extra one.

$$Na^+ + Cl^- \rightarrow NaCl$$

$$\text{Sodium} + \text{chloride yields (table) salt}$$

Covalent Bonding: A **covalent bond** is formed when two atoms *share* electrons, generally in pairs, with one pair from each atom. A single covalent bond is the sharing of one pair of electrons. A double covalent bond is formed when two electron pairs are shared, and a triple covalent bond is formed when three electron pairs are shared. The covalent bond is the strongest of any type of chemical bond and is generally formed between two nonmetals (Figure 6-3).

In a covalently bonded compound, if the electrons in the bond are shared equally, the bond is termed *non-polar.* However, not all elements share electrons equally within a bond. When this occurs, a polar bond is the result, which means that the shared electron density of the bond is concentrated around one atom more than the other. Polarity is based on the difference in electronegativity values for the elements involved in the bond. The greater the difference, the more polar the bond will be, or one end or side of the molecule will have a charge distinctly more positive and the other side of the molecule will be more negative in charge.

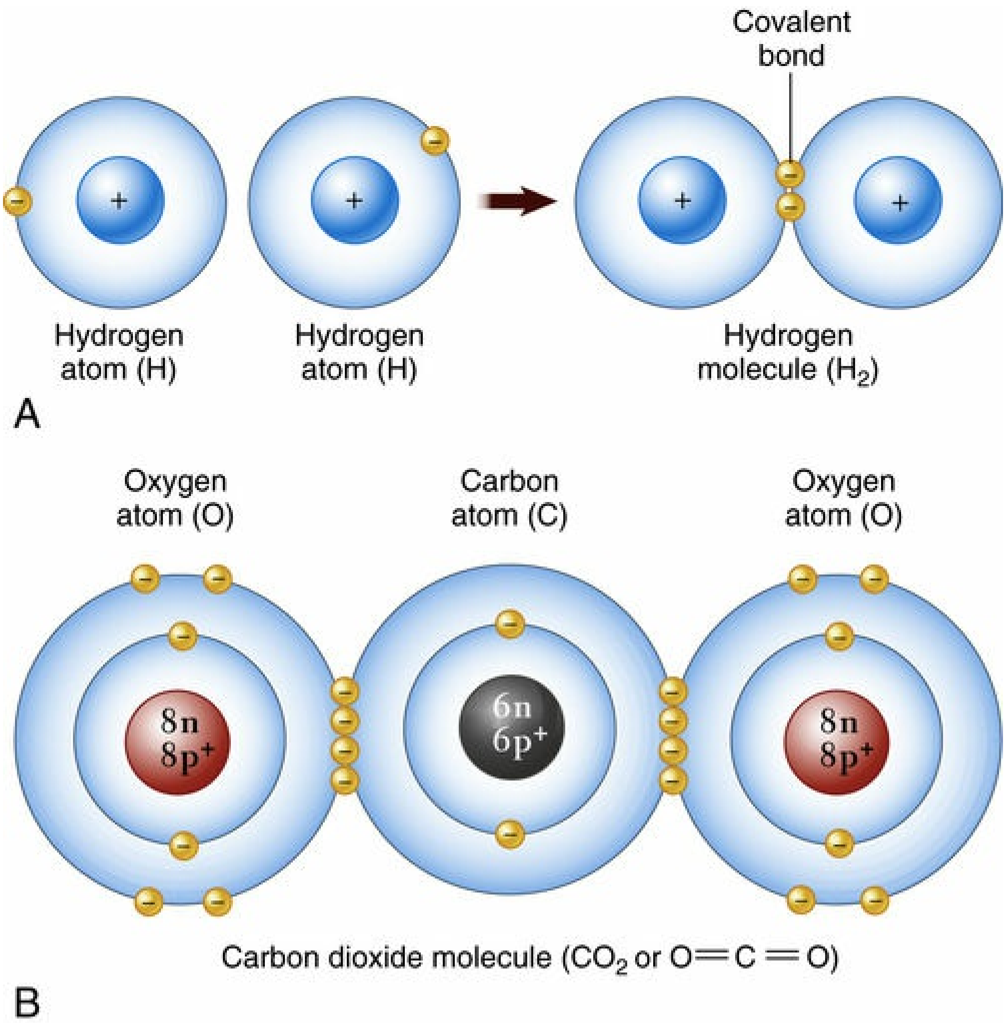

FIGURE 6-3 Types of covalent bonds. **A,** A single covalent bond forms by the

sharing of one electron pair between two atoms of hydrogen, resulting in a molecule of hydrogen gas. **B,** A double covalent bond (double bond) forms by the sharing of two pairs of electrons between two atoms. In this case, two double bonds form: one between carbon and each of the two oxygen atoms. (From Patton KT, Thibodeau GA: *Anatomy and physiology,* ed 9, St. Louis, 2016, Mosby.)

Intermolecular Forces: There are other types of attractions between particles called *intermolecular forces.* These are not bonding interactions between atoms within a molecule but instead are weaker forces of attraction between whole molecules. These forces are hydrogen bonding, dipole-dipole interactions, and dispersion forces.

Hydrogen Bonds: A *hydrogen bond* is the attraction for a hydrogen atom by a highly electronegative element. The elements generally involved are fluorine (F), oxygen (O), and nitrogen (N). Hydrogen bonds are about 5% to 10% as strong as covalent bonds, making them the strongest of the intermolecular forces.

Dipole-Dipole Interactions: A *dipole-dipole interaction* is the attraction of one dipole on one molecule for the dipole of another molecule. A dipole is created when an electron pair is shared unequally in a covalent bond between two atoms or elements (discussed earlier in polar covalent bonding). Because the electrons are shared unequally, the molecule, not the covalent bond, will have a positive end and a negative end or side. In a solution the molecules will align the charged ends of the molecule north to south or positive to negative, where the north end on one molecule is next to the south end of another. The result is a weak bond between molecules, where the more highly electropositive end of a molecule is attracted to the electronegative end of another molecule. This attraction is considered a weak intermolecular force. It is only about 1% as strong as a normal covalent bond.

Dispersion Forces: *Dispersion forces*, sometimes called London dispersion forces, are the weakest of all the intermolecular forces. Sometimes the electrons within an element or compound will concentrate themselves on one side of an atom. This causes a momentary or temporary dipole, which would be attracted to another momentary dipole of opposite charge in another near element or compound.

Stoichiometry

Stoichiometry is the part of chemistry that deals with the quantities and numeric relationships of the participants in a chemical reaction. For a chemical equation to be balanced, numbers called coefficients are placed in front of each compound. These numbers are used in a ratio to compare how much of one substance is needed to react with another in a certain reaction. The process is similar to comparing ingredients in a recipe.

$$2C_2H_6 + 7O^2 \rightarrow 4CO_2 + 6H_2O$$

$$\text{Ethane} + \text{oxygen yields carbon dioxide} + \text{water}$$

Using this reaction, determine the number of moles of oxygen (O_2) that will react with four (4) moles of ethane (C_2H_6). It is possible to determine the number of moles of oxygen needed to complete the reaction by using a process called *dimensional analysis:*

$$\frac{4 \text{ mol } C_2H_6}{} \left| \frac{7 \text{ mol } O_2}{2 \text{ mol } C_2H_6} \right. = 14 \text{ mol } O_2$$

By multiplying the given amount of four moles of ethane by the actual amount of seven moles of Oxygen (O_2) and dividing by the actual number of two moles of ethane (C_2H_6), one can determine that the number of moles of oxygen needed to react will be fourteen.

Oxidation and Reduction

Oxidation/reduction reactions, called *redox,* involve the transfer of electrons from one element to another. *Oxidation is the loss of electrons, and reduction is the gain of electrons.* It is not possible to have one without the other. The element that is oxidized (loses electron) is the reductant or reducing agent, and the element that is reduced (gains electron) is the oxidant or the oxidizing agent. Even though a substance is oxidized and gains an electron, its ionic charge is more negative; likewise, a substance that is reduced loses an electron, and its ionic charge is more positive.

HESI Hint

A good mnemonic is "OIL-RIG" or Oxidation Is Loss (of an electron), Reduction Is Gain (of an electron). Think of it this way: to "reduce" an element, one must cause that element's overall electrical charge to become less, and that is done by adding or gaining one or more negatively charged electrons (e−).

A Redox Reaction

$$\underset{\text{Reduced}}{\text{Oxidant (gains electron)}} + e^{-} \leftrightarrow \underset{\text{Oxidized}}{\text{Reductant (loses electron)}} - e^{-}$$

The oxidant is reduced because it gains an electron. The reductant is oxidized because it loses an electron.

To identify what has been oxidized and what has been reduced, the oxidation states of all elements in the compound must be determined. The following is a series of rules to make those determinations:

1. The oxidation number of any elemental atom is zero. This means that if an element is in its *natural* state, its charge or number is zero. Most elements in their standard states are single atoms, but a few exceptions exist. Those exceptions are hydrogen (H_2), bromine (Br_2), oxygen (O_2), nitrogen (N_2), iodine (I_2), and fluorine (F_2). These elements, when they exist outside of a compound in their natural state, are always in pairs.
2. The oxidation number of any simple ion is the charge of the ion. If in a reaction, sodium (Na) was listed as an ion (Na^+), it would have an oxidation number of plus one (+1). If chlorine (Cl) was listed as an ion (Cl^-), it would have an oxidation number of minus one (−1).
3. The oxidation number for oxygen in a compound is minus two (−2).
4. The oxidation number for hydrogen in a compound is plus one (+1).

5. The sum of the oxidation numbers equals the charge on the molecules or polyatomic ions.

Example: Assign oxidation numbers to all elements in the following reactions.

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

$$\text{Ethane} + \text{oxygen yields carbon dioxide} + \text{water}$$

By using the rules listed earlier, we can use simple algebra to solve for the change of electrical charges of those elements not discussed in the rules. In solving for carbon, the first element in the first reactant, ethane (C_2H_6), we can ignore the coefficient because it has nothing to do with the oxidation states of any of the elements. The total charge on the compound is zero, as is determined using rule five. From rule four, hydrogen must have an oxidation state of +1. There are six hydrogen molecules, so the total charge of the hydrogen molecules is +6. Following is the algebra to solve for the oxidation state of carbon (x):

$$2x + 6(+1) = 0$$

Solving for x, carbon is found to have a charge of −3.

If the same method is used, the states of all the other elements can be determined. Oxygen in O_2 is zero (rule one). Carbon in CO_2 is +4, and oxygen is −2. Finally, hydrogen in water is +1, and oxygen is −2. With this information, it is possible to predict what is oxidized and what is reduced. Look at the charges on either side of the equation and see what has changed. Carbon goes from a state of −3 to a state of +4. It has lost seven electrons and has therefore been oxidized. Oxygen's state has changed from 0 to −2. It has gained two electrons and has therefore been reduced.

Acids and Bases

Acids are corrosive to metals; they change blue litmus paper red and become less acidic when mixed with bases. **Bases,** also called *alkaline compounds,* are substances that denature proteins, making them feel very slick; they change red litmus paper blue and become less basic when mixed with acids.

Acids are compounds that are hydrogen or proton donors. *Hydrogen in its ionic state is simply a proton.* In water naked protons exist only for a short time before reacting with other water molecules to produce H_3O^+, a substance called hydronium. Hydronium is a water molecule plus a proton or hydrogen.

Bases are hydrogen or proton acceptors and generally have a hydroxide (OH) group in the makeup of the molecule. This definition explains the dissociation of water into low concentrations of hydronium and hydroxide ions:

$$H_2O + H_2O \leftrightarrow H_3O^+ + OH^-$$

$$\text{Water} + \text{water yields acid} + \text{base}$$

In this example, one water (H_2O) molecule acts as a hydrogen donor, giving one of its two hydrogens to another water molecule and in the process producing the hydronium (H_3O^+) cation and leaving a hydroxyl group (OH). All acids produce hydronium when placed in H_2O. As can be seen, H_2O is amphoteric, which means it can act both as an acid and as a base. In the example above, one molecule of H_2O acts as the proton donor, becoming a hydroxide (OH), and another molecule acts as the proton acceptor, becoming the conjugate acid (H_3O^+).

The concentration of acids is expressed as **pH.** The pH scale commonly in use ranges from 0 to 14 and is a measure of the acidity or alkalinity of a solution (Figure 6-4). A neutral solution that is neither acidic nor basic has a value of 7. Lower numbers mean more acidic, and higher numbers mean more basic.

Nuclear Chemistry

Chemical and nuclear reactions are quite different. In chemical reactions, atoms are trying to reach stable electron configurations. Nuclear chemistry is concerned with reactions that take place in the nucleus to obtain stable nuclear configurations. *Radioactivity* is the word used to describe the emission of particles and/or energy from an unstable nucleus. The particles and/or energy that are emitted are referred to as *radiation*. The three types of radiation in nuclear chemistry are alpha, beta, and gamma.

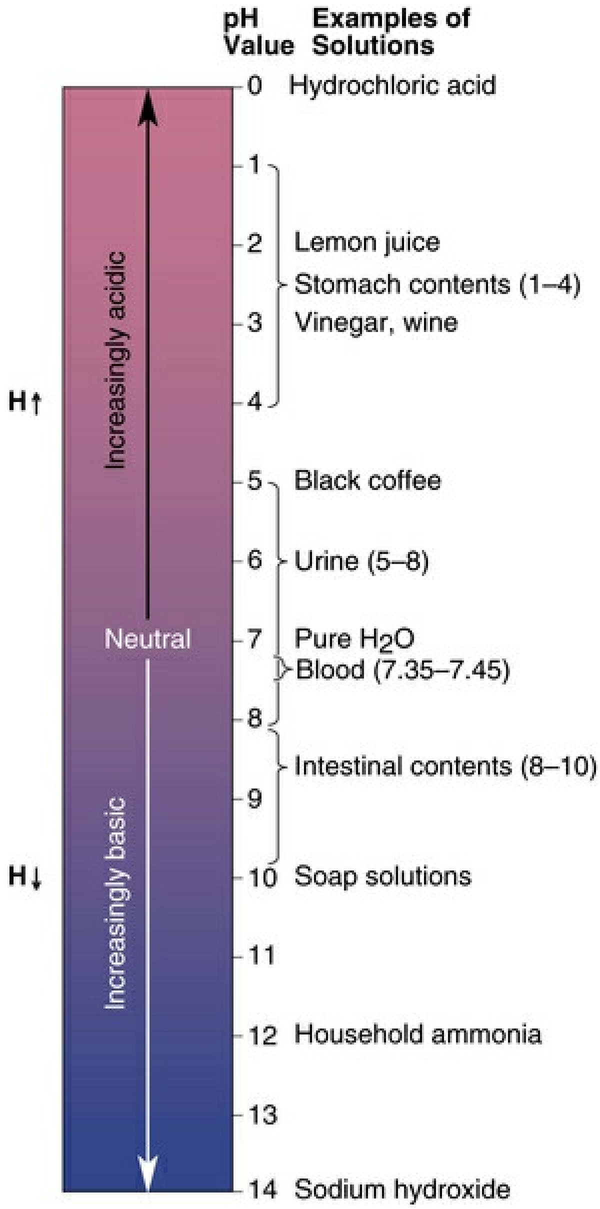

FIGURE 6-4 The pH range. (From Herlihy: The human body in health and illness, ed 5, St. Louis, 2014, Saunders.)

Alpha radiation is the emission of helium nuclei. These particles contain two protons and two neutrons, causing them to have a charge of plus two (+2). Alpha particles are the largest of the radioactive emissions, and penetration from alpha particles can generally be stopped by a piece of paper.

Beta radiation is a product of the decomposition of a neutron or proton. It is actually composed of high-energy, high-speed electrons that began as neutrons or protons. These particles are either negatively charged (electrons) or positively charged (positrons). Because they have virtually no mass, beta particles can be stopped by a thin sheet of aluminum foil, Lucite, or plastic.

Gamma radiation is high-energy electromagnetic radiation, similar to x-rays but with more energy. It is very penetrating and can go through several feet of concrete or several inches of lead. Lead shielding is required to block gamma rays.

An isotope is written as an abbreviation with the symbol of the element preceded by a superscript number indicating the atomic mass. For example, Iodine-131 is correctly abbreviated as ^{131}I, and Iodine-125 would be written as ^{125}I. In nature, some isotopes are stable and some isotopes are unstable. Given enough time, unstable nuclei will change or "decay" into more stable forms. The amount of time it takes for half of the unstable isotope to decay is called the half-life. In nuclear chemistry the unstable atom *decays* until it finds a stable nuclear configuration, usually by emitting radioactive particles. The amount of time used in a half-life ($T^{1/2}$) is different for every radioactive element. Some half-lives are very long, and some are as short as a few days. An example of radioactive half-life or decay is ^{131}I, which has a half-life of approximately 8 days, or every 8 days one-half of the radioactive particles will be emitted or decayed. This will happen over and over again until the ^{131}I reaches a stable nuclear configuration.

Biochemistry

Biochemistry is the study of chemical processes in living organisms. Much of biochemistry deals with the structures and functions of molecules such as carbohydrates, proteins, lipids, and nucleic acids.

Carbohydrates

Sugars and starches are carbohydrates. Their most important function is to store and provide energy for the body. The sugars **deoxyribose** and **ribose** are used in the formation of deoxyribonucleic acid (DNA) and ribonucleic acid (RNA), respectively. Carbohydrates are more abundant than any other known type of biomolecule.

Monosaccharides The simplest type of carbohydrate is a monosaccharide. Monosaccharides contain carbon, hydrogen, and oxygen, in a ratio of 1:2:1 (general formula $C_m (H_2O)_n$), where m is at least three). Glucose ($C_6H_{12}O_6$) is one of the most important carbohydrates and is an example of a monosaccharide. Fructose ($C_6H_{12}O_6$), the sugar commonly associated with the sweet taste of fruits, is also a monosaccharide. Glucose and fructose are both a six-carbon sugar called a *hexose* (Figure 6-5).

HESI Hint

The word "saccharide" comes from a Greek word meaning "sugar."

HESI Hint

Glucose and fructose have the same chemical formula ($C_6H_{12}O_6$) but different actual molecular configurations.

Disaccharides Two monosaccharides can be joined together to make a disaccharide. The most well-known disaccharide is sucrose, which is ordinary sugar. Sucrose consists of a glucose molecule and a fructose molecule joined together. Another disaccharide is lactose, or milk sugar, consisting of a glucose molecule and a galactose molecule. Figure 6-6 illustrates the molecular configuration of sucrose and lactose.

Oligosaccharides and Polysaccharides When three to six monosaccharides are joined together, it is called an *oligosaccharide* (oligo- meaning "few"). More than six and up to thousands of monosaccharides joined together make a *polysaccharide,* which can be called a *starch.* Two of the most common polysaccharides are cellulose, made by plants, and glycogen, made by animals, and both of these polysaccharides are chains of repeating glucose units.

Carbohydrates as Energy

Glycolysis Glucose is mainly metabolized by a chemical pathway in the body called glycolysis. The net result is the breakdown of one molecule of glucose into two molecules of pyruvate; this also produces a net two molecules of adenosine triphosphate (ATP). ATP is the substance cells use for energy. In aerobic cells with sufficient oxygen, like most human cells, the pyruvate is further metabolized by a process called *oxidative phosphorylation* (Krebs cycle) generating more molecules of ATP, water, and carbon dioxide. Using oxygen to completely oxidize glucose provides an organism with far more energy than any oxygen-deficient system.

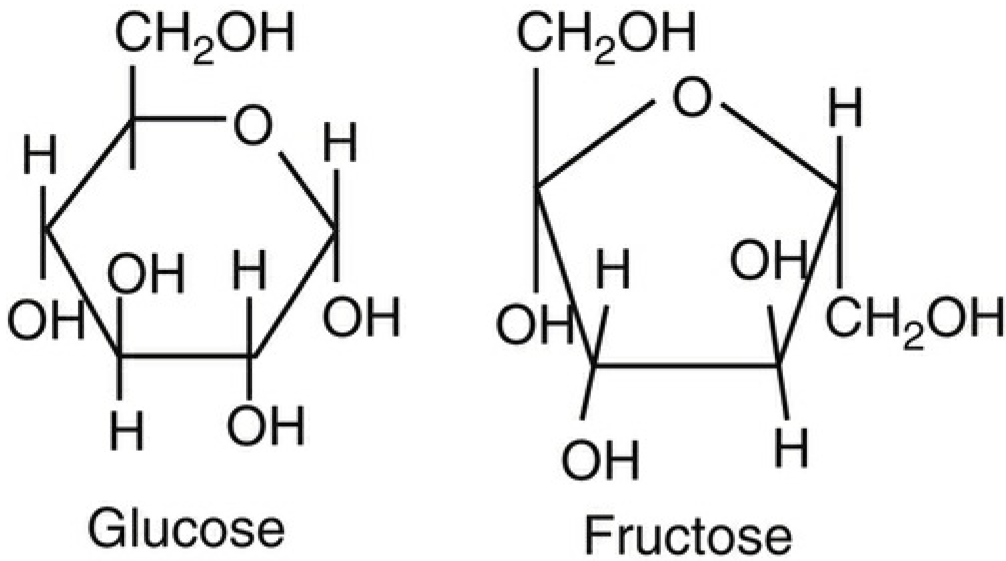

FIGURE 6-5 Molecular configuration for glucose and fructose.

When skeletal muscles are used in vigorous exercise, they will not have enough oxygen to meet their energy demands. They will need to use another type of glucose metabolism called anaerobic glycolysis. Anaerobic means in the absence of or without oxygen. This process converts glucose to lactate instead of pyruvate as in aerobic glycolysis. The production of lactate, an acid, in the muscles creates the "burning or cramping" sensation during intense exercise.

HESI Hint

An aerobic organism or cell requires oxygen to sustain life. An anaerobic organism or cell can function in low concentrations of oxygen, also called micro-aerobic, and some anaerobic organisms exist with no oxygen present.

Gluconeogenesis The liver can make glucose from other noncarbohydrate sources, such as proteins and parts of fats, using a process called gluconeogenesis. The glucose produced can then enter the energy-producing

cycles mentioned previously and undergo glycolysis, or glucose can be stored as glycogen in animals or as cellulose in plants. Glucose can also be used to make other saccharides.

Proteins

Proteins are made up of amino acids. An amino acid is a molecule composed of a carbon atom bonded with four other groups: an amine group (NH_2), a carboxyl group (COOH), a hydrogen, and an R group (Figure 6-7). The R group is different for each amino acid, giving each amino acid its own identity and characteristics. Amino acids are joined together to make proteins or parts of proteins. A union of two amino acids using a peptide bond is called a *dipeptide;* groups of fewer than 30 amino acids are called peptides or polypeptides. Larger groups are referred to as proteins. As an example, an important protein in blood called *albumin* contains 585 amino acid residues, and albumin is considered a fairly small protein. In humans, there are only 20 amino acids needed to make all the proteins necessary for life.

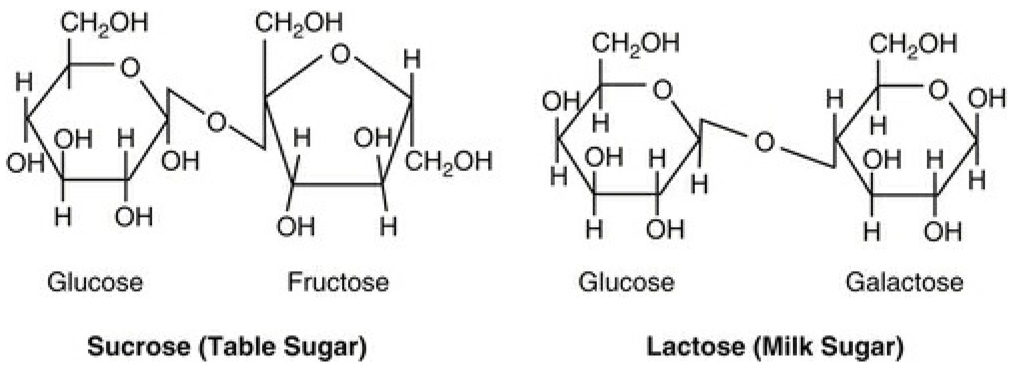

FIGURE 6-6 Molecular configuration for sucrose and lactose.

Lipids

Lipids are fats and encompass a large group of molecules, including oils, fats, and fatty acids. Fatty acids consist of a hydrocarbon chain with an acid group, the carboxyl group (COOH), at one end. A neutral fat (triglyceride) is three fatty acids generally joined to a glycerol or some other backbone structure (Figure 6-8). Phospholipids are similar to neutral fats, but one of the three fatty acids is replaced by a phosphate group. Cholesterol is yet another form of fat composed of a four-ring structure and a side chain. Fats are used by the body to insulate body organs against shock, to maintain body temperature, to keep skin and hair healthy, and to promote healthy cell function. Phospholipids are essential components of cell membranes, and cholesterol is an obligatory precursor for many important biologic molecules such as steroid hormones. Fats also serve as energy stores for the body.

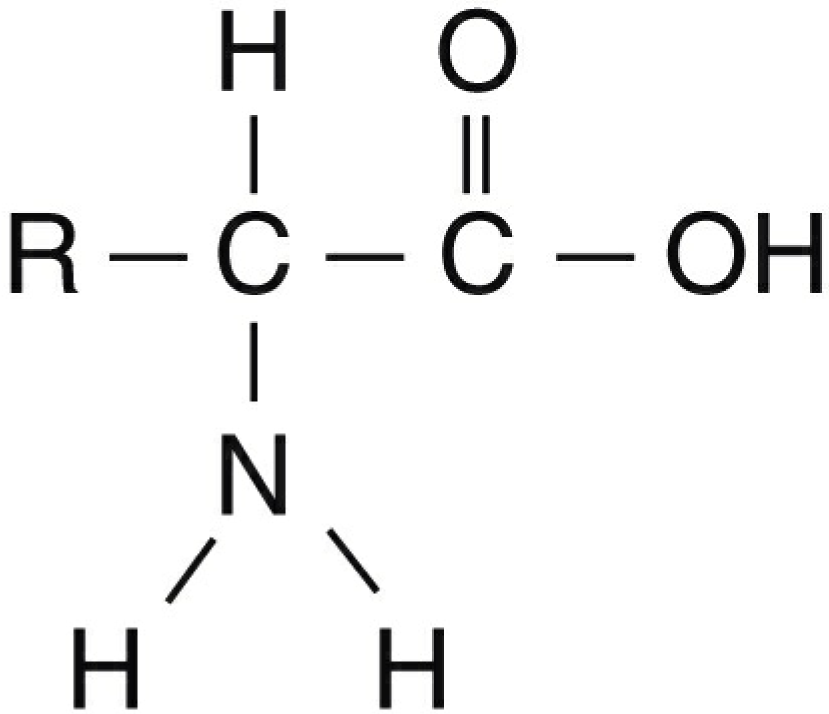

FIGURE 6-7 An amino acid general formula.

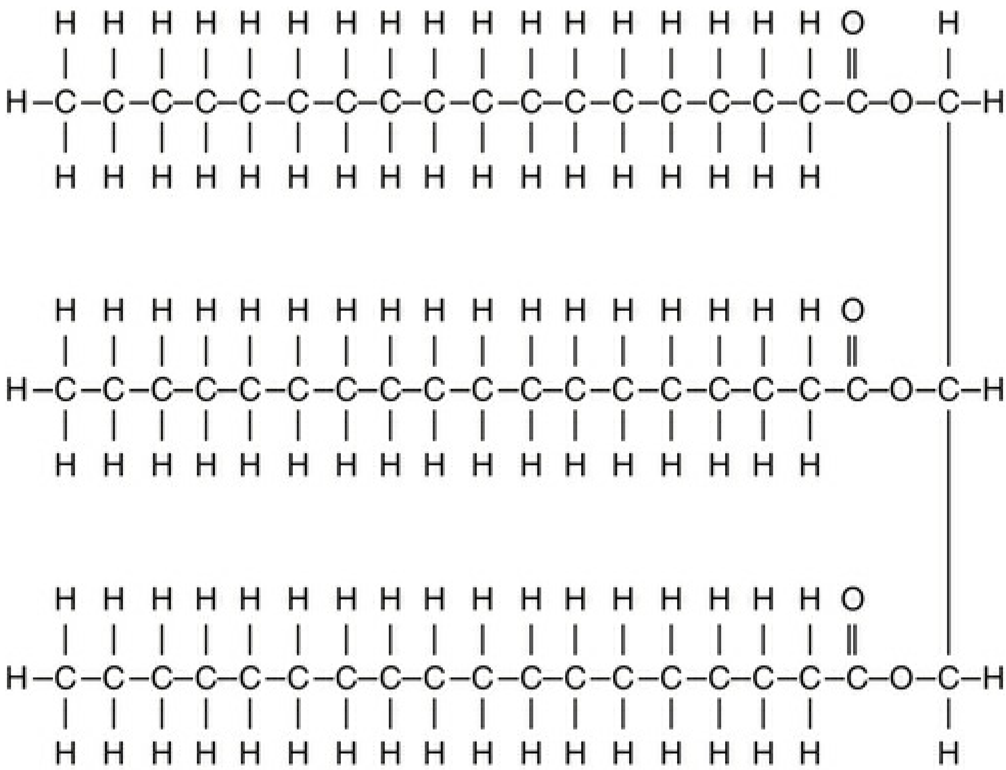

FIGURE 6-8 Three fatty acids attached to a glycerol.

Lipids are found in many foods, such as oils, milk, and milk products such as butter and cheese. Natural lipids can be classified as unsaturated,

polyunsaturated, and saturated. Saturated fats have no double bond between carbon atoms of the fatty acid chains (Figure 6-9). Unsaturated fats have one or more double bonds between some of the carbon atoms of the fatty acid chains and are more desirable in our diet than saturated fats (Figure 6-10).

Nucleic Acids

Nucleic acids are the biologic brain of life, telling the cell what it will do and how to do it. They include DNA and RNA. Both are nucleotide chains that convey genetic information. Nucleic acids are found in all living cells and viruses. Most nucleic acids are found in the nucleus, but some are found in the cytoplasm and mitochondria of individual cells. They are very large molecules that have two main parts.

The backbone of the molecule DNA is composed of deoxyribose, a five-carbon sugar that is also called a pentose, and a phosphate, which alternately chain together in a "sugar-phosphate-sugar-phosphate" chain, making two very long structures. The two chains, or strands, actually twist around each other like the strands of a rope, which is referred to as a "double helix."

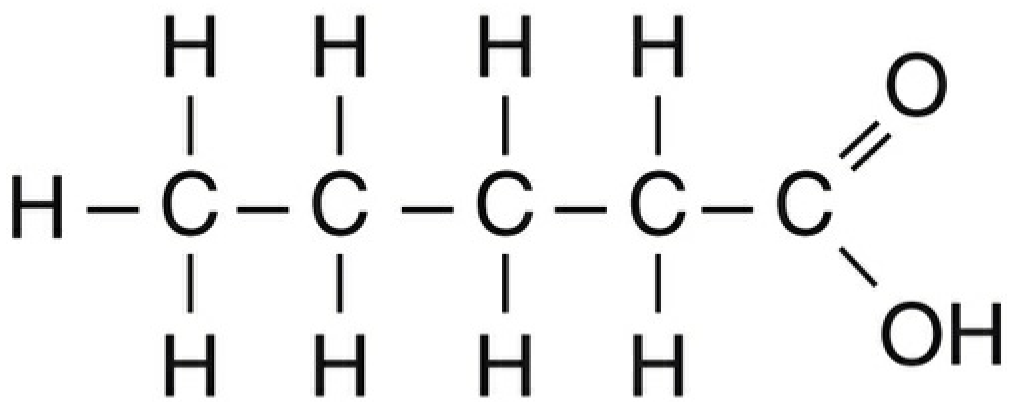

FIGURE 6-9 An example of a saturated fatty acid.

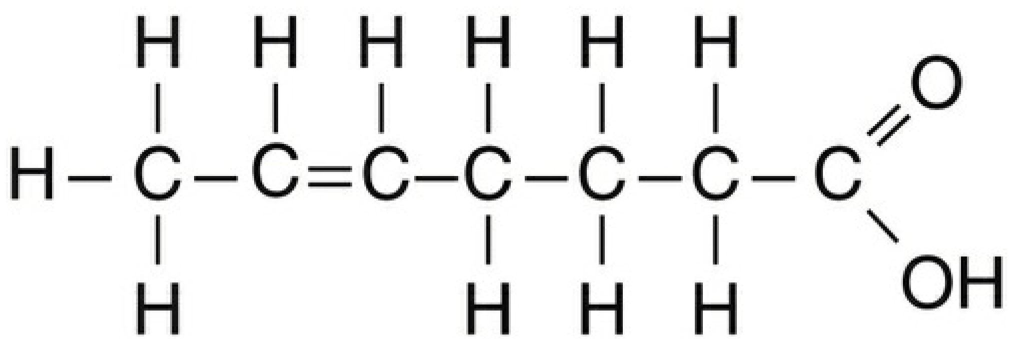

FIGURE 6-10 An example of an unsaturated fatty acid. Note that there are two hydrogens missing, and there is a double bond, designated by two lines, between the two carbons in the center of the fatty acid.

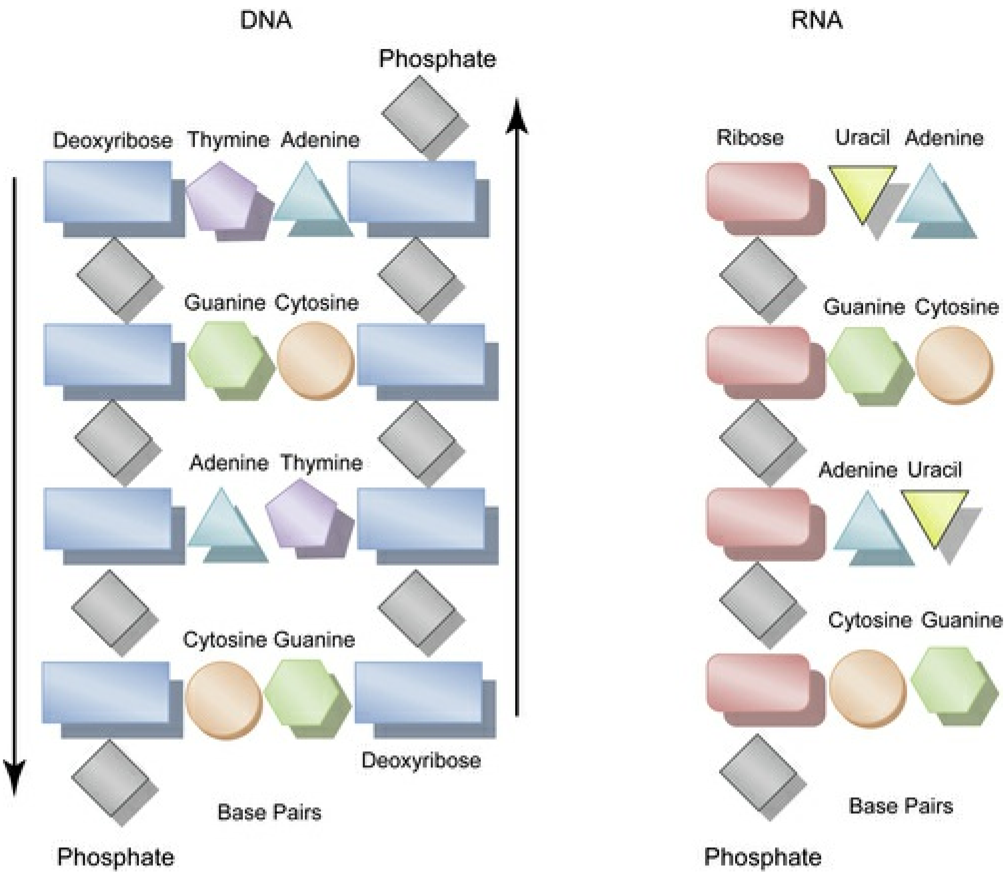

FIGURE 6-11 Structure of DNA and RNA. (Note: The double helix is not illustrated here.)

The DNA bases adenine, cytosine, guanine, and thymine join the two chains from sugar to sugar much like the rungs of a ladder in a base pair relationship. The pair relationships are constant in that adenine and thymine are always bound together and cytosine and guanine are always bound together in DNA. Note that the two sugar-phosphate chains in DNA run in opposite directions: one up and one down. This is termed *anti-parallel.*

The structure of RNA differs from DNA's structure in that RNA is a single strand of ribose, a five-carbon carbohydrate, in a sugar-phosphate chain (Figure 6-11). RNA does not use thymine to form one of its base pairs; it uses instead uracil to bind with adenine. Cytosine and guanine are the other base pair.

Review Questions

1. An individual who weighs 125 lb weighs how much in kilograms?
   A. 56.8 kg
   B. 2750 kg
   C. 68.5 kg
   D. 100 kg
2. How many protons does potassium (K) have? Refer to the Periodic table.
   A. 39.08
   B. 32
   C. 19
   D. 13
3. How many neutrons does carbon 14 (^{14}C) have?
   A. 6
   B. 7
   C. 8
   D. 9
4. What would be the oxidation state of the sulfur atom in sulfuric acid, H_2SO_4?
   A. +4
   B. +5
   C. +6
   D. +8
5. What is the strongest type of chemical bond?
   A. Covalent
   B. Hydrogen
   C. Ionic
   D. Dipole interactions
6. Acids are:
   A. Proton acceptors
   B. Proton donors
   C. Electron acceptors
   D. Electron donors
7. When two monosaccharides are joined together they make a:
   A. Polysaccharide
   B. Oligosaccharide
   C. Disaccharide

D. Fat

8. The nucleic acids DNA and RNA:

A. Are found in the cell nucleus

B. Are not found in the cell mitochondria

C. Contain different kinds of fat

D. Include very small molecules

9. The reaction $2C_2H_6$ (g) + $7O_2$ (g) → $4CO_2$ (g) + $6H_2O$ (g) or ethane + oxygen yields carbon dioxide + water is an example of:

A. Combustion

B. Double replacement

C. Single replacement

D. Decomposition

10. What is the correct name for $MgSO_4$?

A. Magnesium sulfate

B. Manganese

C. Magnesium sugar

D. Manganese silicate

11. Amphoteric refers to the ability of water to be both a base and a peptide. True or False?

12. How many amino acids are in a dipeptide?

A. 3

B. An even number

C. An odd number

D. 2

13. Glycogen is:

A. A plant starch

B. A disaccharide

C. An animal starch

D. Not a starch or a disaccharide

14. Gluconeogenesis is a process that produces:

A. Energy and ATP

B. Glucose from proteins and fats

C. DNA and RNA

D. Fat from glucose and proteins

15. The 3 in the power of 10^3 is called the:

A. Coefficient

B. Significand

C. Subscript

D. Exponent

16. A pentose is:

A. Pentateuch

B. A 5-carbon sugar

C. One of the bases of the base pairs in DNA and RNA

D. Found in DNA but not RNA

17. How many amino acids are essential for human life?

A. 20

B. 22

C. As many as 585

D. Amino acids are not essential for life.

Answers to Review Questions

1. A
2. C
3. C
4. C
5. A
6. B
7. C
8. A
9. A
10. A
11. False
12. D
13. C
14. B
15. D
16. B
17. A

Anatomy and Physiology

CHAPTER OUTLINE

KEY TERMS

Alimentary Canal
Anatomic Position
Anterior
Appendicular Skeleton
Arterioles
Axial Skeleton
Bolus
Cell
Cerebellum
Cerebrum

Chyme
Dermis
Distal
Epidermis
Erythrocytes
Estrogen
External Respiration
Hemopoiesis
Histology
Inferior
Infundibulum
Internal Respiration
Lateral
Leukocytes
Medial
Medulla Oblongata
Meiosis
Mitosis
Neuroglia
Osteoblasts
Platelets
Posterior
Progesterone
Proximal
Sarcomeres
Superior
Synergists
Voluntary Muscles

Every student in the health professions should know the basics of anatomy and physiology. From cells and tissues to organs and systems, the human body is one of the most complex organism on earth. It is important that members of the health professions who take care of clients know how the human body works as a whole and what role specific parts of the body play in an individual's health and well-being.

A one-year course in anatomy and physiology should be taken before the

student prepares for the anatomy examination. Take the time to read about anatomy and physiology at every opportunity. This preparation guide will go through each of the major body systems and point out the most important aspects of facts that should be learned.

General Terminology

Students of anatomy and physiology should learn the standard terms for body directions and subdivisions of the body. These will provide a basic introduction to the study of the body and also point out the need for the use of correct terminology.

The body planes are imaginary lines used for reference; they include the median plane, the coronal plane, and the transverse plane. A section is a real or imaginary cut made along a plane. A cut along the median plane is a sagittal section. A cut along the coronal plane is a frontal section, and a cut through the transverse plane is a cross-section. When describing the body, visualize the **anatomic position.** The body is erect, the feet are slightly apart, the head is held high, and the palms of the hands are facing forward.

Important terms of direction to review include **superior** (above), **inferior** (below), **anterior** (facing forward), **posterior** (toward the back), **medial** (toward the midline), and **lateral** (away from the midline or toward the sides). **Proximal** and **distal** are terms of direction usually used in reference to limbs. Proximal means closer to the point of attachment, and distal refers to farther away from the point of attachment. Figure 7-1 depicts the directional terms.

Major body cavities are divided into the dorsal cavity (includes the cranial and spinal cavities) and the ventral cavity (includes the orbits and the nasal, oral, thoracic, and abdominopelvic cavities).

Additional useful terminology is defined later in this chapter.

Histology

Histology is the study of tissues. A tissue is a group of cells that act together to perform specific functions. The four fundamental tissues are epithelial, connective, muscle, and nerve tissues (Figure 7-2). Epithelial cells cover, line, and protect the body and its internal organs. Connective tissue is the framework of the body, providing support and structure for the organs. Nerve tissue is composed of neurons and connective tissue cells that are referred to as **neuroglia.** Muscle tissues have the ability to contract or shorten. Muscle tissue is classified as voluntary muscle (skeletal muscles) or involuntary muscle (smooth muscle and cardiac muscle tissue).

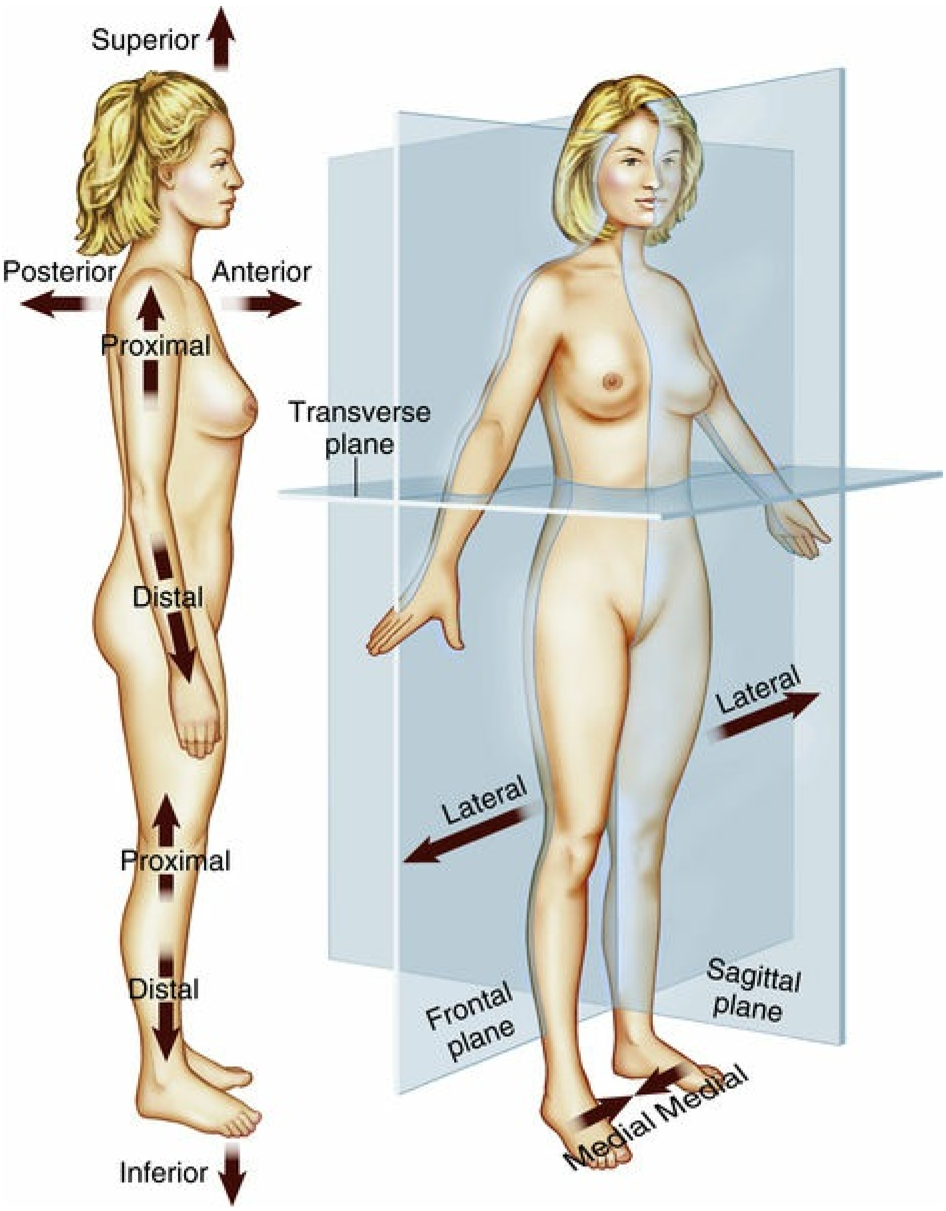

FIGURE 7-1 Planes and directions of the body. (From Patton KT, Thibodeau GA:

Anatomy and physiology, ed 8, St Louis, 2013, Mosby.)

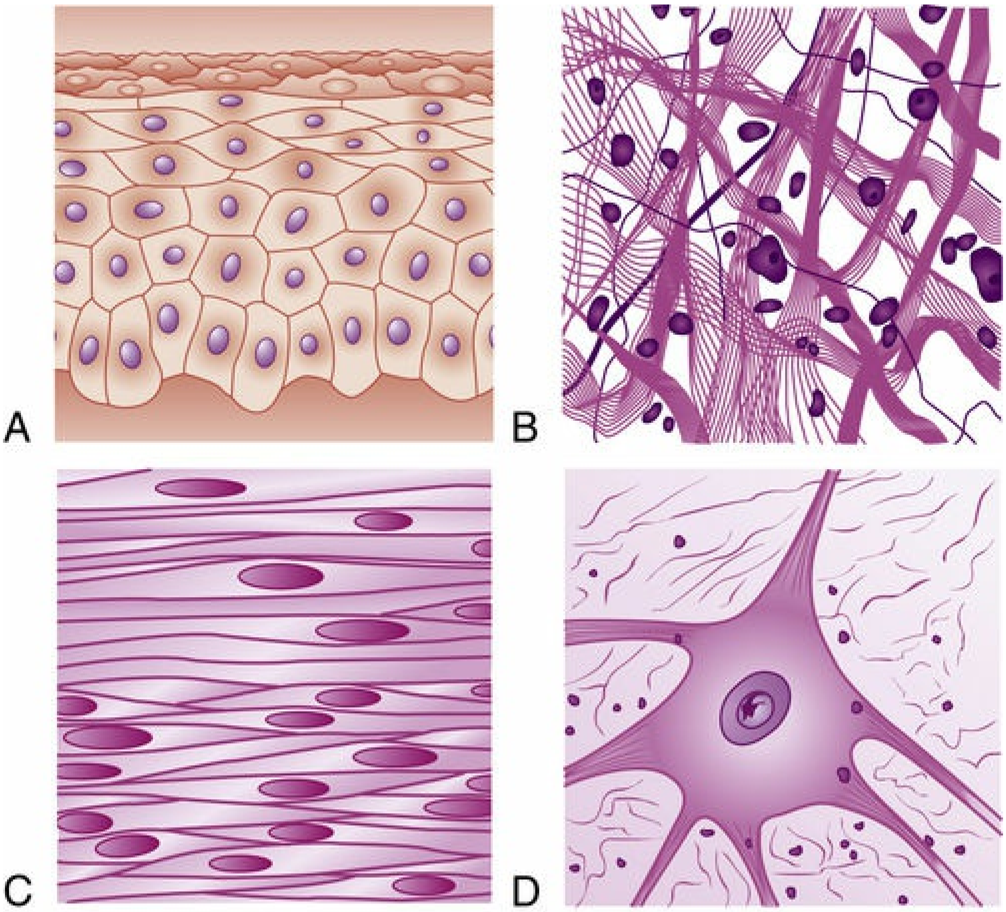

FIGURE 7-2 Major tissues of the body. **A,** Epithelial tissue; **B,** connective tissue; **C,** muscle tissue; **D,** nervous tissue. (From Patton KT, Thibodeau GA: *Anatomy and physiology,* ed 9, St Louis, 2016, Mosby.)

The major parts of the cell should be reviewed. The **cell** is the basic unit of life and the building block of tissues and organs. Within the cell, each organelle has a specific function. The nucleus, which contains deoxyribonucleic acid (DNA), and ribosomes are especially important in the synthesis of proteins. Proteins include the enzymes that regulate all chemical reactions within the body.

Mitosis and Meiosis

Mitosis is necessary for growth and repair. In this process, the DNA is duplicated and distributed evenly to two daughter cells. Meiosis is the special cell division that takes place in the gonads, that is, the ovaries and testes. In the process of **meiosis,** the chromosome number is reduced from 46 to 23, so when the egg and the sperm unite in fertilization, the zygote will have the correct number of chromosomes.

Skin

The skin is the largest organ of the body. The skin consists of two layers: the **epidermis** (the outermost protective layer made of dead, keratinized epithelial cells) and the **dermis** (the underlying layer of connective tissue with blood vessels, nerve endings, and the associated skin structures). The dermis rests on the subcutaneous tissue that connects the skin to the superficial muscles.

The layers of the epidermis, from outer layer to inner layer, are the stratum corneum, the stratum lucidum, the stratum granulosum, and the innermost stratum germinativum (includes stratum basale and stratum spinosum), where **mitosis** occurs. Epidermal cells contain the protein pigment called *melanin,* which protects against radiation from the sun.

The inner layer of the skin is the dermis, composed of fibrous connective tissue with blood vessels, sensory nerve endings, hair follicles, and glands. There are two types of sweat glands. The most widely distributed sweat glands regulate body temperature by releasing a watery secretion that evaporates from the surface of the skin. This type of sweat gland is known as eccrine. The other sweat glands, mainly in the armpits and groin area, display apocrine secretion. This secretion contains bits of cytoplasm from the secreting cells. This cell debris attracts bacteria, and the presence of the bacteria on the skin results in body odor. The sebaceous glands release an oily secretion (sebum) through the hair follicles that lubricates the skin and prevents drying. Sebum is produced by holocrine secretion, in which whole cells of the gland are part of the secretion. These glands are susceptible to becoming clogged and attracting bacteria, particularly during adolescence.

The appendages of the skin include hair and nails. Both are composed of a strong protein called *keratin.* Skin structure is illustrated in Figure 7-3. Hair, nails, and skin may show changes in disease that may be used in the diagnosis of clinical conditions. For example, skin cancer is a clinical condition that is associated with the skin.

HESI Hint

As the epidermal cells move from the deepest layers to the superficial layers, they move away from their blood and nutrient supply; subsequently, they dehydrate and die. To illustrate this, visualize a large transparent container filled with inflated balloons covered with sticky glue. This illustrates the stratum basale. As the balloons deflate, the sides that are stuck together pull the balloons into a spiny shape, much like the stratum spinosum. As the balloons continue to deflate, they become flattened, like the stratum corneum.

Skeletal System

The body framework consists of bone, cartilage, ligaments, and joints. Functions of the skeletal system include support, movement, blood cell formation **(hemopoiesis),** protection of internal organs, detoxification (removal of poisons), provision for muscle attachment, and mineral storage (particularly calcium and phosphorus).

Individual bones are classified by shape. There are long bones, short bones, flat bones, irregular bones, and sesamoid bones. A typical long bone has an irregular epiphysis at each end, composed mainly of spongy (cancellous) bone, and a shaft or diaphysis, composed mainly of compact bone. The cells that form compact bone are called **osteoblasts;** when they become fixed in the dense bone matrix, they stop dividing but continue to maintain bone tissue as osteocytes.

The **axial skeleton** (Figure 7-4) consists of the skull, vertebral column, twelve pairs of ribs, and sternum. When including the 6 paired bones (ossicles) of the ear, the skull is comprised of 28 bones—14 facial bones and 14 cranial vault bones. The facial bones include two nasal bones, two maxillary bones, two zygomatic bones, one mandible (the only moveable bone of the skull), two palatine bones, one vomer, two lacrimal bones, and two inferior nasal conchae. The bones of the cranium are the single occipital, frontal, ethmoid, and sphenoid and the paired parietal, temporal, and ossicles of the ear (malleus, incus, and stapes).

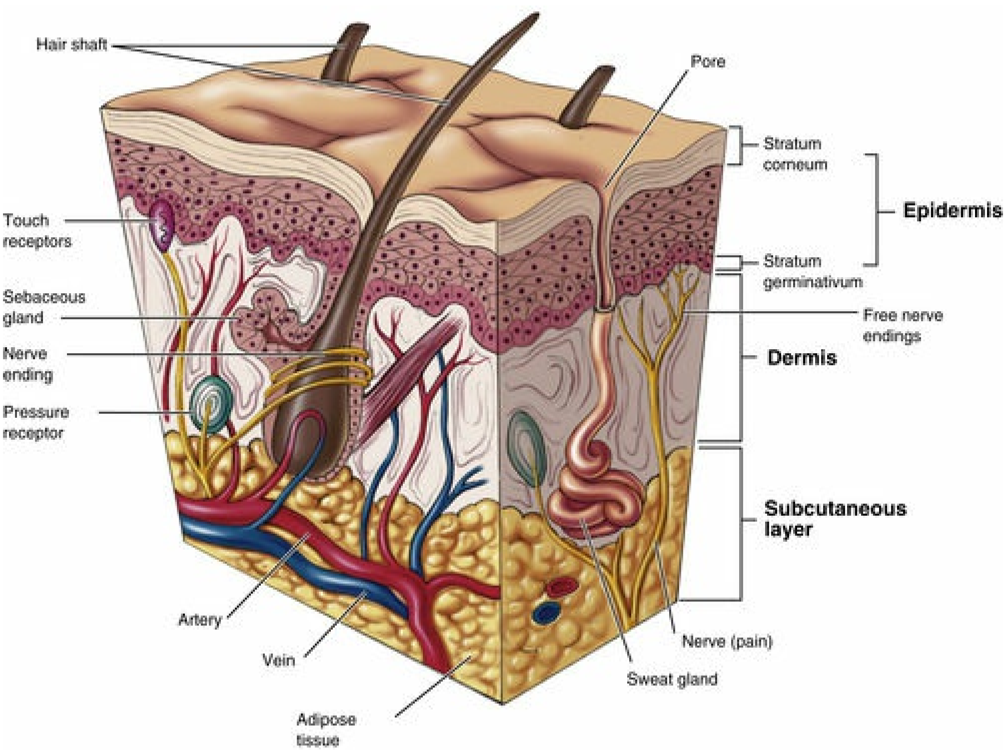

FIGURE 7-3 Diagram of skin structure. **A,** Thick skin, found on surfaces of the palms and soles of the feet. **B,** Thin skin, found on most surface areas of the

body. (From Herlihy: *The human body in health and illness*, ed 5, St. Louis, 2014, Saunders.)

The vertebral column is divided into five subsections, as depicted in Figure 7-5. There are 7 cervical vertebrae, 12 thoracic vertebrae, 5 lumbar vertebrae, 5 sacral vertebrae (which fuse to form the sacrum), and the coccygeal vertebrae (known as the tailbone*).*

The **appendicular skeleton** (see Figure 7-4) includes the girdles and the limbs. The upper portion consists of the pectoral or shoulder girdle, the clavicle and scapula, and the upper extremity. The bones of the arm are the humerus, the radius and ulna, the carpals (wrist bones), the metacarpals (bones of the hand), and the phalanges (bones of the fingers). The lower portion of the appendicular skeleton is made up of the pelvic girdle or os coxae. Each of the os coxae consists of a fused ilium, ischium, and pubis. Bones of the lower extremity include the femur (thighbone), the tibia and fibula, the tarsals (ankle bones), the metatarsals (bones of the foot), and the phalanges.

HESI Hint

Construct flash cards for learning the names, locations, and other features of bones and bone markings. Time and practice are more successful learning strategies than trying to "get it" on the first or second time through. Use mnemonic devices to recall the names and positions of bones, foramina, and other anatomic groups within the skeleton.

Muscular System

Muscles produce movement by contracting in response to nervous stimulation. Muscle contraction results from the sliding together of actin and myosin filaments within the muscle cell or fiber. Each muscle cell consists of myofibrils, which in turn are made up of still smaller units called **sarcomeres.** Calcium and adenosine triphosphate (ATP) must be present for a muscle cell to contract. Nervous stimulation from motor neurons causes the release of calcium ions from the sarcoplasmic reticulum. Calcium ions attach to inhibitory proteins on the actin filaments within the cell, moving them aside so that cross-bridges can form between actin and myosin filaments. Using energy supplied by ATP, the filaments slide together to produce contraction.

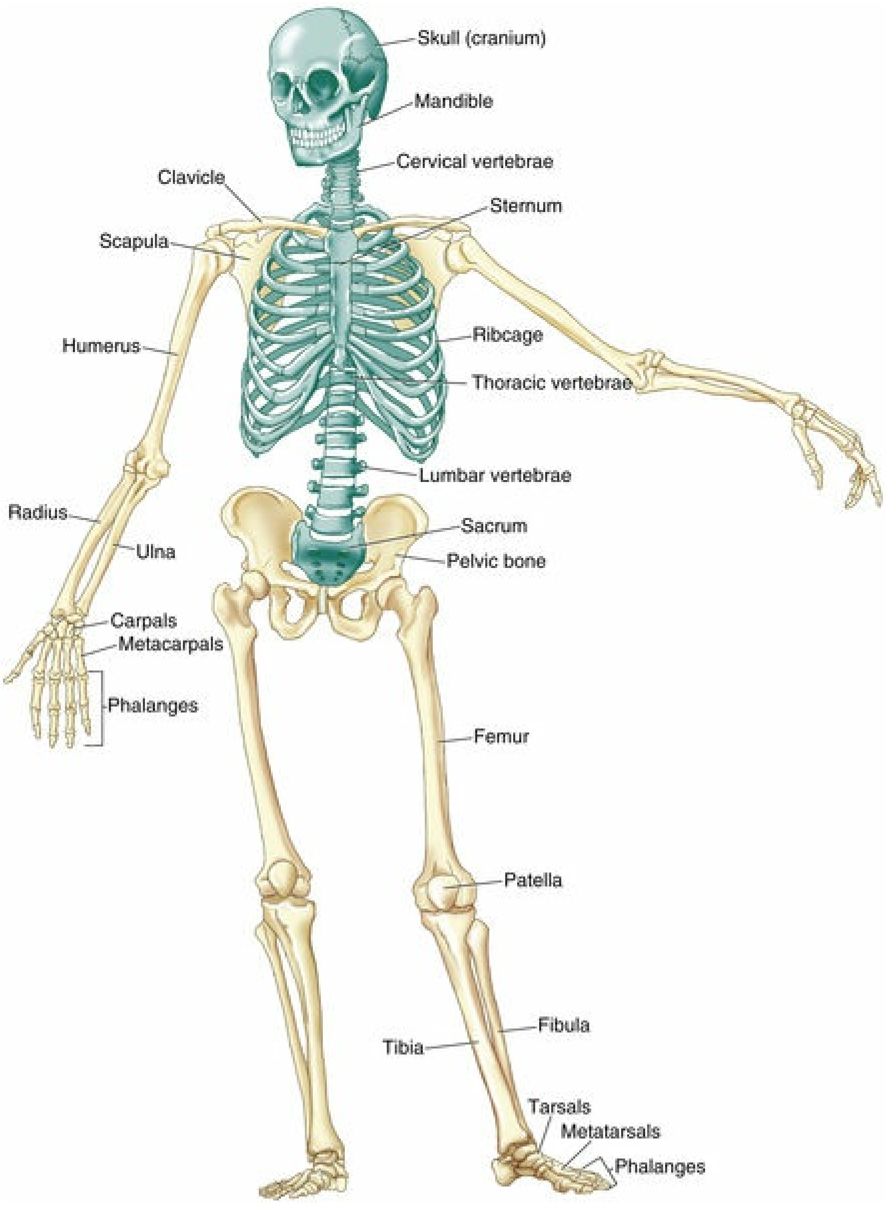

FIGURE 7-4 Bones colored beige are bones of the appendicular skeleton; bones colored green are bones of the axial skeleton. (From Muscolino: Kinesiology: *the skeletal system and muscle function,* ed 2, St Louis, 2011, Mosby.)

The skeletal muscles, which make up the muscular system, are also called **voluntary muscles** because they are under conscious control. Skeletal muscles must work in pairs: the muscle that executes a given movement is the prime mover, whereas the muscle that produces the opposite movement is the antagonist. Other muscles known as **synergists** may work in cooperation with the prime mover.

Muscles can be classified according to the movements they elicit. Flexors reduce the angle at the joint, whereas extensors increase the angle. Abductors draw a limb away from the midline, and adductors return the limb back toward the body (Figure 7-6).

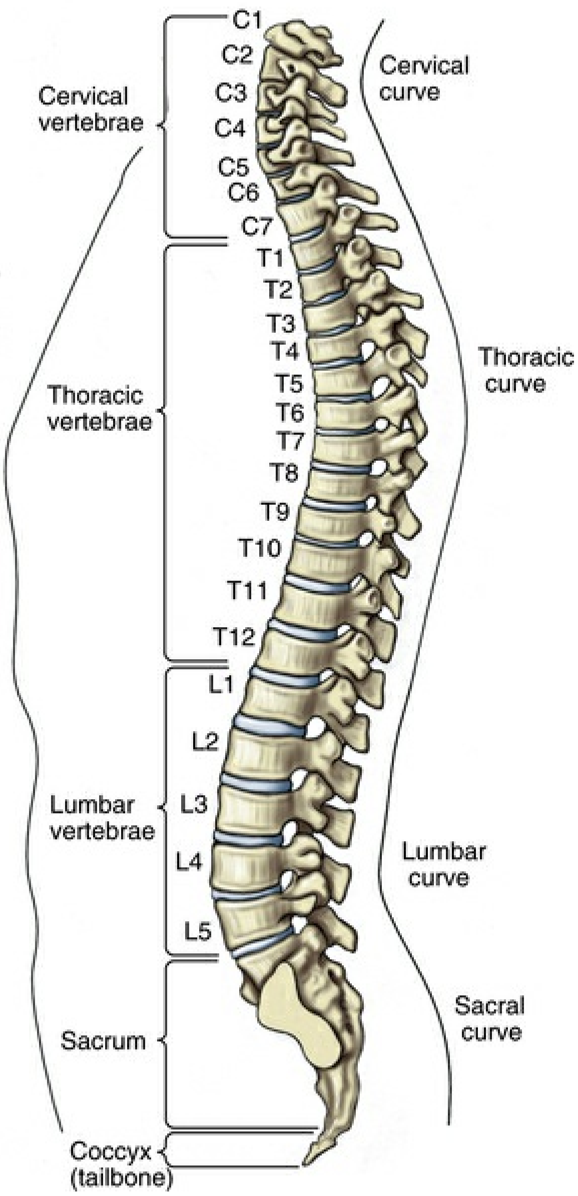

FIGURE 7-5 Vertebral column. (From Herlihy: *The human body in health and illness*, ed 5, St. Louis, 2014, Saunders.)

HESI Hint

The names of muscles are usually descriptive of their shape, location, and/or points of attachment. For example, the sternocleidomastoid muscle's attachments are given in its name. The extra time taken in learning the Latin origins of the muscle names might be well worth the benefits it provides in learning new material later.

Nervous System

The nervous system consists essentially of the brain, the spinal cord, and the nerves (Figure 7-7). This vital system enables us to perceive many of the changes that take place in our external and internal environments and to respond to those changes (seeing, hearing, tasting, smelling, and touching are examples of perception). It enables us to think, reason, remember, and carry out other abstract activities. It makes body movements by skeletal muscles possible by supplying them with nerve impulses that cause contraction. It works closely with the endocrine glands, correlating and integrating body functions such as digestion and reproduction.

All actions of the nervous system depend on the transmission of nerve impulses over neurons, or nerve cells, the functional units of the nervous system. The main parts of a neuron are the cell body, axon, and dendrites. Dendrites transmit the impulse toward the cell body, and axons transmit the impulse away from the cell body.

The nervous system may be divided structurally into a central nervous system (CNS) and a peripheral nervous system (PNS) (see Figure 7-7). The CNS is compromised of the spinal cord and brain, while the PNS is composed of all other neurons in the body. Sensory (afferent) neurons transmit nerve impulses toward the CNS. Motor (efferent) neurons transmit nerve impulses away from the CNS toward the effector organs such as muscles, glands, and digestive organs.

The major parts of the brain are the **cerebrum** (associated with movement and sensory input), the **cerebellum** (responsible for muscular coordination), and the **medulla oblongata** (controls many vital functions such as respiration and heart rate).

The spinal cord is approximately 18 inches long and extends from the base of the skull (foramen magnum) to the first or second lumbar vertebra (L1 or L2). Thirty-one pairs of spinal nerves exit the spinal cord. Simple (spinal) reflexes are those in which nerve impulses travel through the spinal cord only and do not reach the brain.

HESI Hint

Most reflex pathways involve impulses traveling to and from the brain in ascending and descending tracts of the spinal cord. Sensory impulses enter the dorsal horns of the spinal cord, and motor impulses leave through the ventral horns of the spinal cord.

Endocrine System

The endocrine system assists the nervous system in homeostasis and plays important roles in growth and sexual maturation. These two systems meet at the hypothalamus and pituitary gland. The hypothalamus governs the pituitary and is in turn controlled by the feedback of hormones in the blood. The nervous and endocrine systems coordinate and control the body, but the endocrine system has more long-lasting and widespread effects. Figure 7-8 shows the locations of some major endocrine glands.

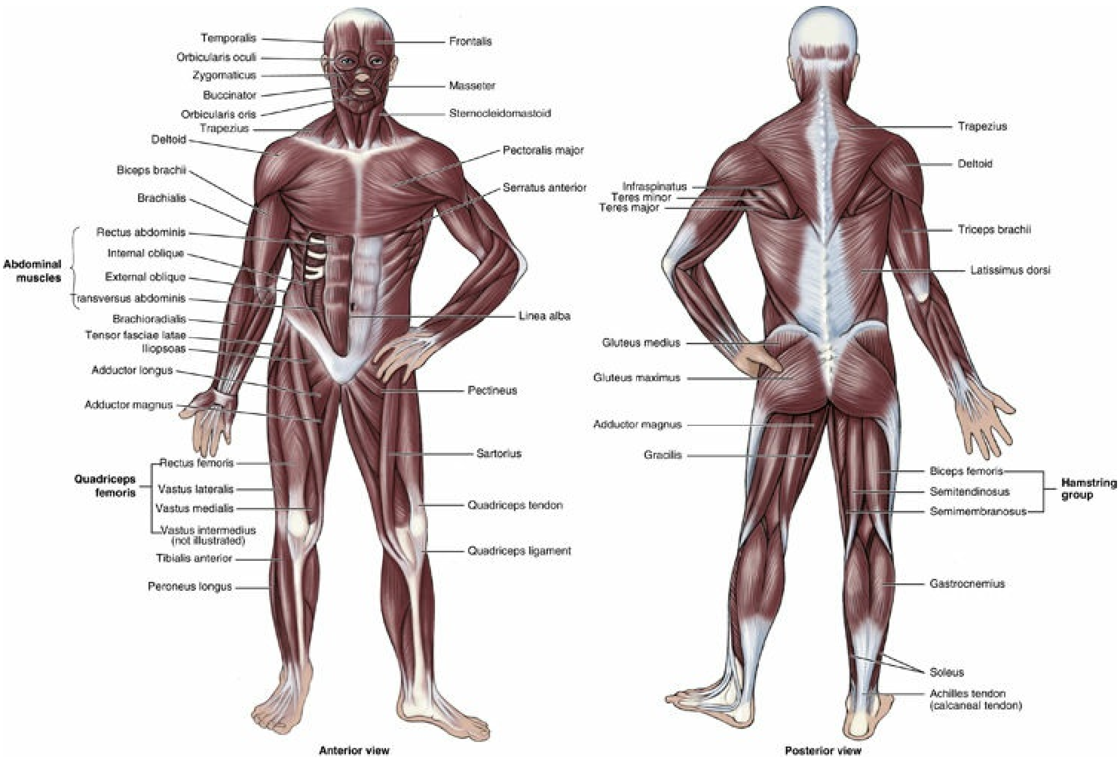

FIGURE 7-6 General overview of the body's musculature (anterior and posterior view). (From Herlihy: *The human body in health and illness,* ed 5, St. Louis, 2014, Saunders.)

Hormones are chemical messengers that control the growth, differentiation, and metabolism of specific target cells. There are two major groups of hormones, steroid and nonsteroid hormones. Steroid hormones enter the target cells and have a direct effect on the DNA of the nucleus. Some nonsteroid hormones are protein hormones. Many protein hormones remain at the cell surface and act through a second messenger, usually a substance called *adenosine monophosphate* (AMP). Most hormones affect cell activity by altering the rate of protein synthesis.

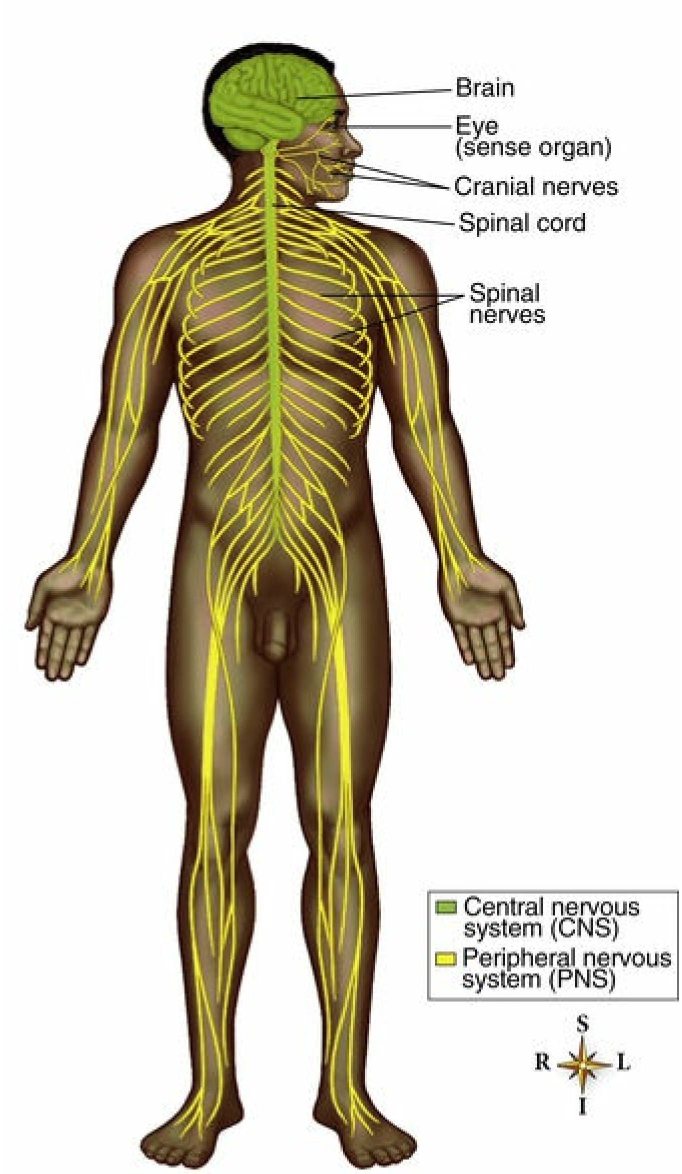

FIGURE 7-7 Major anatomic features of the nervous system include the brain, the spinal cord, and the individual nerves. The central nervous system (CNS) consists of the brain and spinal cord. The peripheral nervous system (PNS) includes all of the nerves and their branches. (From Patton KT, Thibodeau GA: *Anatomy and physiology*, ed 9, St Louis, 2016, Mosby.)

The endocrine glands, although widely distributed, are grouped together as a system because the main function of each gland is the production of hormones. Other organs, such as the stomach, small intestine, and kidneys, produce hormones as well.

HESI Hint

Multiple hormones are released during stress from the adrenal cortex, the hypothalamus, and the posterior and anterior pituitary. The cortisol released from the adrenal cortex reduces inflammation, raises the blood sugar level,

and inhibits the release of histamine.

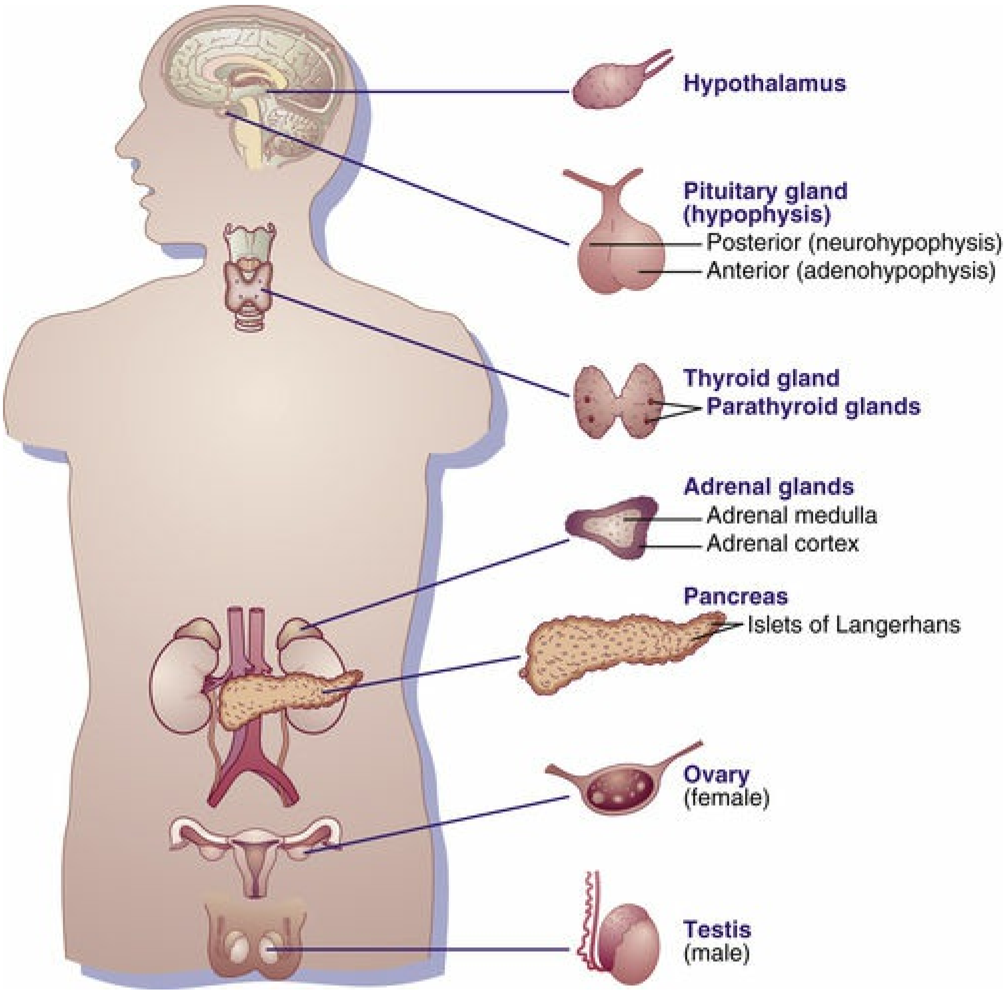

FIGURE 7-8 Locations of some major endocrine glands. (From Kee: *Pharmacology: a patient-centered nursing process approach*, ed 8, St Louis, 2015, Saunders.)

The pituitary gland is nicknamed the master gland. It is attached to the hypothalamus by a stalk called the **infundibulum.** The pituitary gland has two major portions: the anterior lobe (adenohypophysis) and the posterior lobe (neurohypophysis). Hormones of the adenohypophysis are called *tropic hormones* because they act mainly on other endocrine glands. They include the following:

- Somatotropin hormone (STH) or growth hormone (GH)
- Adrenocorticotropic hormone (ACTH)
- Thyroid-stimulating hormone (TSH)
- Follicle-stimulating hormone (FSH)
- Luteinizing hormone (LH)

Hormones released from the posterior lobe of the pituitary include oxytocin (the labor hormone) and antidiuretic hormone (ADH).

Other important endocrine glands include the thyroid, parathyroids, adrenals, pancreas, and gonads (the ovaries and testes).

Circulatory System

Whole blood consists of approximately 55% plasma and 45% formed elements: **erythrocytes** (red blood cells), **leukocytes** (white blood cells), and **platelets.** All of the formed elements are produced from stem cells in red bone marrow. Erythrocytes are modified for transport of oxygen. Most of this oxygen is bound to the pigmented protein hemoglobin. The five types of leukocytes can be distinguished on the basis of size, appearance of the nucleus, staining properties, and presence or absence of visible cytoplasmic granules. White blood cells are active in phagocytosis (neutrophils and monocytes) and antibody formation (lymphocytes). Platelets are active in the process of blood clotting.

Blood serves to transport oxygen and nutrients to body cells and to carry away carbon dioxide and metabolic wastes. Plasma contains approximately 10% proteins, ions, nutrients, waste products, and hormones, which are dissolved or suspended in water.

The heart is a double pump that sends blood to the lungs for oxygenation through the pulmonary circuit and to the remainder of the body through the systemic circuit. Blood is received by the atria and is pumped into circulation by the ventricles. Valves between the atria and ventricles include the tricuspid on the right side of the heart and the bicuspid on the left. Semilunar valves are found at the entrances of the pulmonary trunk and the aorta. Blood is supplied to the heart muscle (the myocardium) by the coronary arteries. Blood drains from the myocardium directly into the right atrium through the coronary sinus.

The heart has an intrinsic beat initiated by the sinoatrial node and transmitted along a conduction system through the myocardium. This wave of electrical activity is what is measured on an electrocardiogram (ECG). The cardiac cycle is the period from the end of one ventricular contraction to the end of the next ventricular contraction. The contraction phase of the cycles is systole; the relaxation phase is diastole.

The vascular system includes arteries that carry blood away from the heart, veins that carry blood toward the heart, and the capillaries. The capillaries, the smallest of vessels, are where the exchanges of water, nutrients, and waste products take place between the blood and surrounding tissues. The systemic arteries begin with the aorta, which sends branches to all parts of the body. As arteries get farther away from the heart, they become thinner and thinner. The smallest arteries are called **arterioles.** The veins parallel the arteries and usually have the same names. The superior and inferior venae cavae are the large veins that empty into the right atrium of the heart.

The walls of the arteries are thick and elastic, and they carry blood under high pressure. Vasoconstriction and vasodilation result from contraction and relaxation of smooth muscle in the arterial walls. These changes influence blood pressure and blood distribution to the tissues. The walls of the veins are thinner and less elastic than those of the arteries, and they carry blood under lower pressure. Figure 7-9 provides an overall view of the circulatory system.

HESI Hint

Deflections of the ECG do not represent the systole and diastole of the heart chambers. Instead, they represent the electrical activity that precedes the contraction-relaxation events of the myocardium. An analogy for this is the situation at a track meet when the starter's gun is fired before the runners start to run. The sound initiates the action. In the heart, the action potential is similar to firing the gun. The contraction starts just after the action potential passes over the muscle cells.

Respiratory System

Components of the respiratory system include the nose, pharynx, larynx, trachea, bronchi, lungs with their alveoli, diaphragm, and muscles surrounding the ribs. The structural plan of the respiratory system is shown in Figure 7-10. Respiration is controlled by the respiratory control center in the medulla of the brain.

The respiratory system supplies oxygen to the body and eliminates carbon dioxide. **External respiration** refers to the exchange of gases between the atmosphere and the blood through the alveoli. **Internal respiration** refers to the exchange of gases between the blood and the body cells. The passageways between the nasal cavities and the alveoli conduct gases to and from the lungs. The upper passageways also serve to warm, filter, and moisten incoming air. These upper respiratory tubules are lined with cilia that help to trap debris and keep foreign substances from entering the lungs.

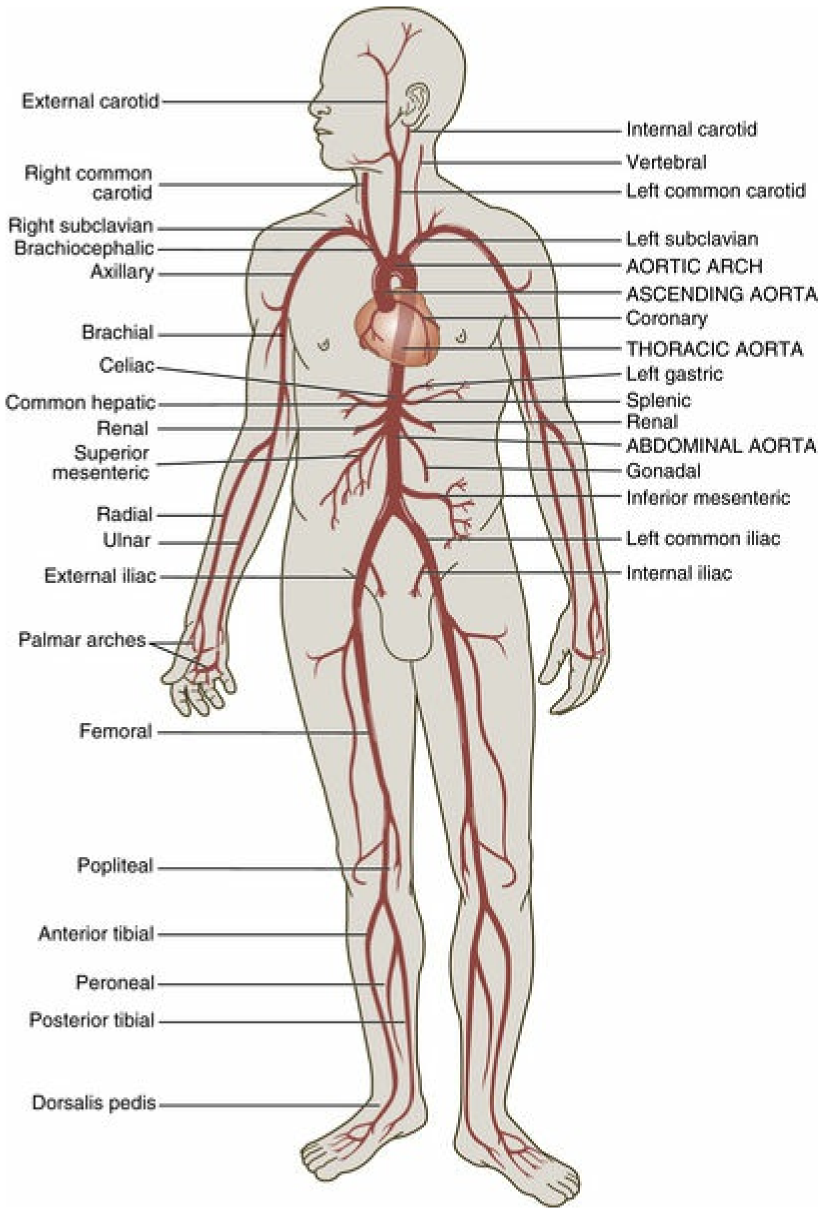

FIGURE 7-9 Principal arteries of the body. (From Applegate: *The anatomy and physiology learning system,* ed 4, St Louis, 2011, Saunders.)

Inhalation requires the contraction of the diaphragm to enlarge the thoracic cavity and draw air into the lungs. Exhalation is a passive process during which the lungs recoil as the respiratory muscles relax and the thorax decreases in size.

Most of the oxygen carried in the blood is bound to hemoglobin in red blood cells. Oxygen is released from hemoglobin as the concentration of oxygen drops in the tissues. Some carbon dioxide is carried in solution or bound to blood proteins, but most is converted to bicarbonate ions by carbonic anhydrase within red blood cells. Because this reaction also releases hydrogen ions, carbon dioxide is a regulator of blood pH.

HESI Hint

Using the familiar example of an inverted tree, you can quickly visualize the trachea as the trunk and the two primary bronchi and their many subdivisions as the branches. The analogy of a bunch of grapes can then be used to explain the terminal components of the respiratory tract, which include the alveolar ducts, alveolar sacs, and alveoli.

Digestive System

The **alimentary canal** or digestive tube consists of the mouth, pharynx, esophagus, stomach, small intestine, large intestine, rectum, and anus. The accessory organs of digestion include the liver, pancreas, and gallbladder. The locations of the digestive organs are seen in Figure 7-11.

Food is ingested into the mouth, where it is mechanically broken down by the teeth and tongue in the process of mastication (chewing). Saliva, produced by the three pairs of salivary glands, lubricates and dilutes the chewed food. Saliva contains an enzyme called amylase that starts the digestion of complex carbohydrates. A ball of food called a **bolus** is formed. Constrictive muscles of the pharynx force the food into the upper portion of the esophagus, and the food is swallowed. The esophagus is a narrow tube leading from the pharynx to the stomach. The digestive tract has four main layers, from innermost to outer: the mucous membrane, the submucous layer, the muscular layer, and the serous layer.

Food enters the stomach where gastric glands secrete hydrochloric acid that breaks down foods. The stomach muscle churns and mixes the bolus of food, turning the mass into a soupy substance called **chyme.** The stomach also stores food and regulates the movement of food into the small intestine.

Digestion and absorption of food occur in the small intestine. Here, food is acted on by various enzymes from the small intestine and pancreas and by bile from the liver. The pancreas also contributes water to dilute the chyme and bicarbonate ions to neutralize the acid from the stomach. The small intestine consists of three major regions: the duodenum, the jejunum, and the ileum. Nutrients are absorbed through the walls of the small intestine. The amino acids and simple sugars derived from proteins and carbohydrates are absorbed directly into the blood. Most of the fats are absorbed into the lymph by the lacteals, which eventually are added to the bloodstream. All nutrients then enter the hepatic portal vein to be routed to the liver for decontamination. Small fingerlike projections called *villi* greatly increase the surface area of the intestinal wall.

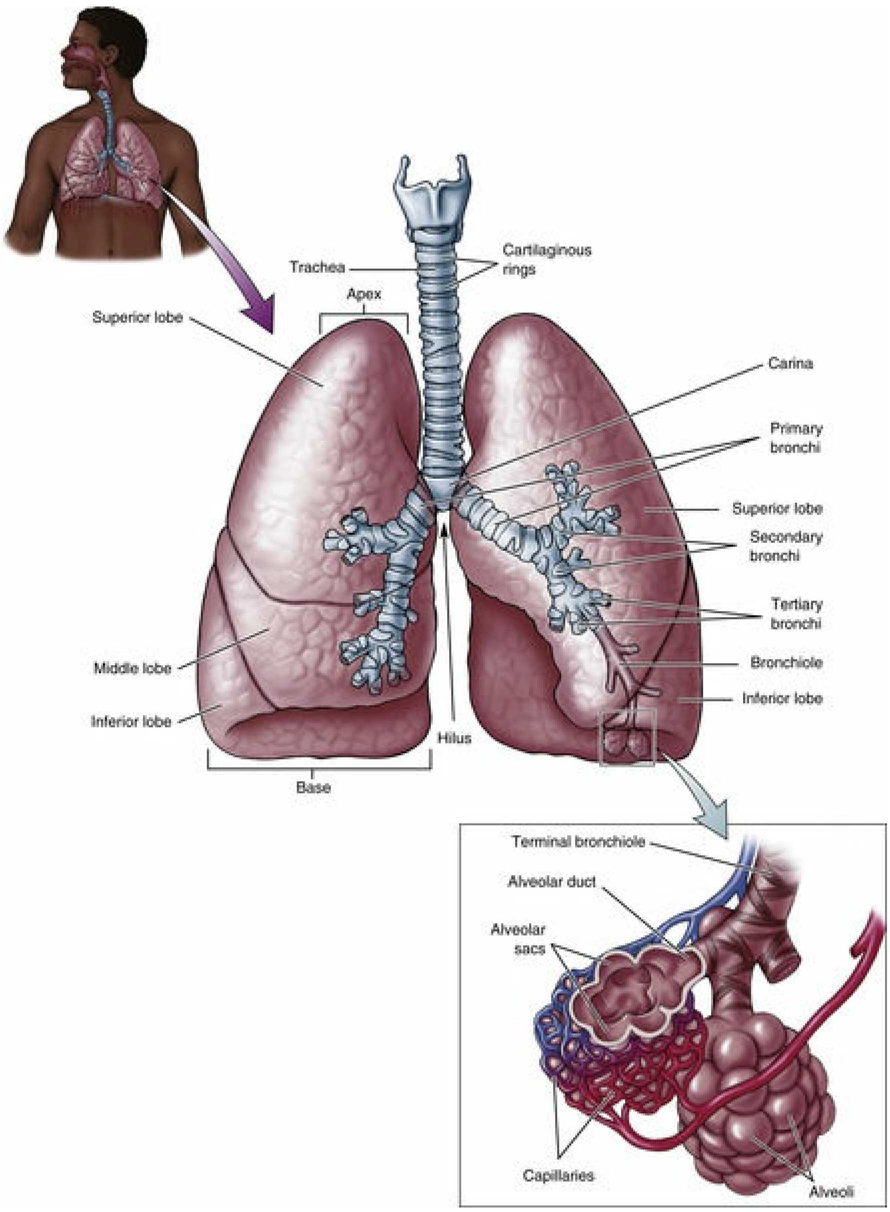

FIGURE 7-10 Structural plan of the respiratory system. (From Herlihy: *The human body in health and illness,* ed 5, St. Louis, 2014, Saunders.)

The large intestine reabsorbs water and stores and eliminates undigested food. Here also are abundant bacteria, the intestinal flora. The large intestine is arranged into five portions: the ascending colon, the transverse colon, the descending colon, the sigmoid colon, and the rectum. The opening for defecation (expelling of stool) is the anus.

HESI Hint

During mastication, the teeth reduce ingested food material to smaller particles to increase surface area for chemical digestion. Collectively, a bowl of ping-pong balls has far more surface area than a basketball. The muscular movements of the stomach and intestines also result in mechanical

breakdown of food, thus increasing surface area for digestion.

Urinary System

The urinary system consists of two kidneys, two ureters, a urinary bladder, and the urethra. The kidneys filter the blood. The ureters are tubes that transport urine to the urinary bladder, where urine is stored before urination through the urethra to the outside. Locations of urinary system organs are illustrated in Figure 7-12. The functional units of the kidney are the nephrons. These small coiled tubes filter waste material out of blood brought to the kidney by the renal artery. The actual filtration process occurs through the glomerulus in Bowman's capsule of the nephron. Filtration of the blood occurs through the glomerulus under the force of blood pressure. As the glomerular filtrate passes through the nephron, components needed by the body, such as water, glucose, and ions, leave the nephron by diffusion and reenter the blood. Water is reabsorbed at the tubules of the nephron. The final product produced by the millions of nephrons per kidney is urine.

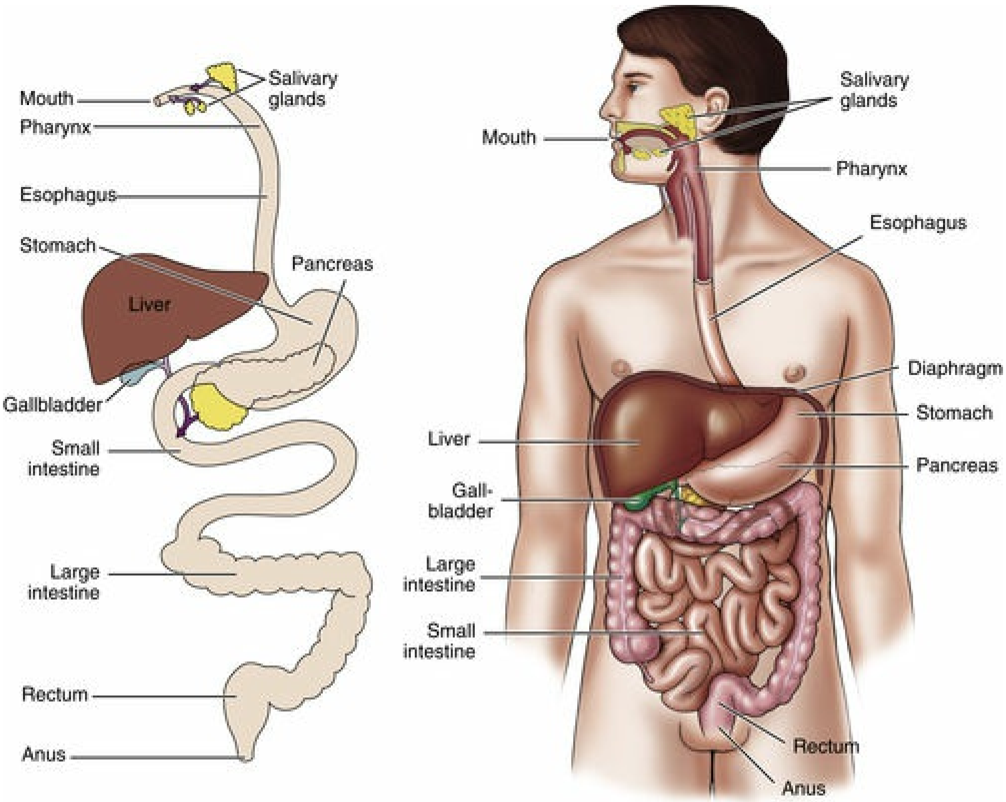

FIGURE 7-11 Location of the digestive organs. (From Herlihy: *The human body in health and illness*, ed 5, St. Louis, 2014, Saunders.)

HESI Hint

The analogy of a wastewater treatment facility linked to an incredibly efficient recycling center may help you understand the big picture of urinary system function. The central role of the kidneys is to serve as regulators of our internal environment. Most chemical exchanges with blood occur in the kidneys, where they filter and process the blood to produce urine. In effect, they launder the body fluids of liquid sewage and at the same time retain essential chemicals and nutrients.

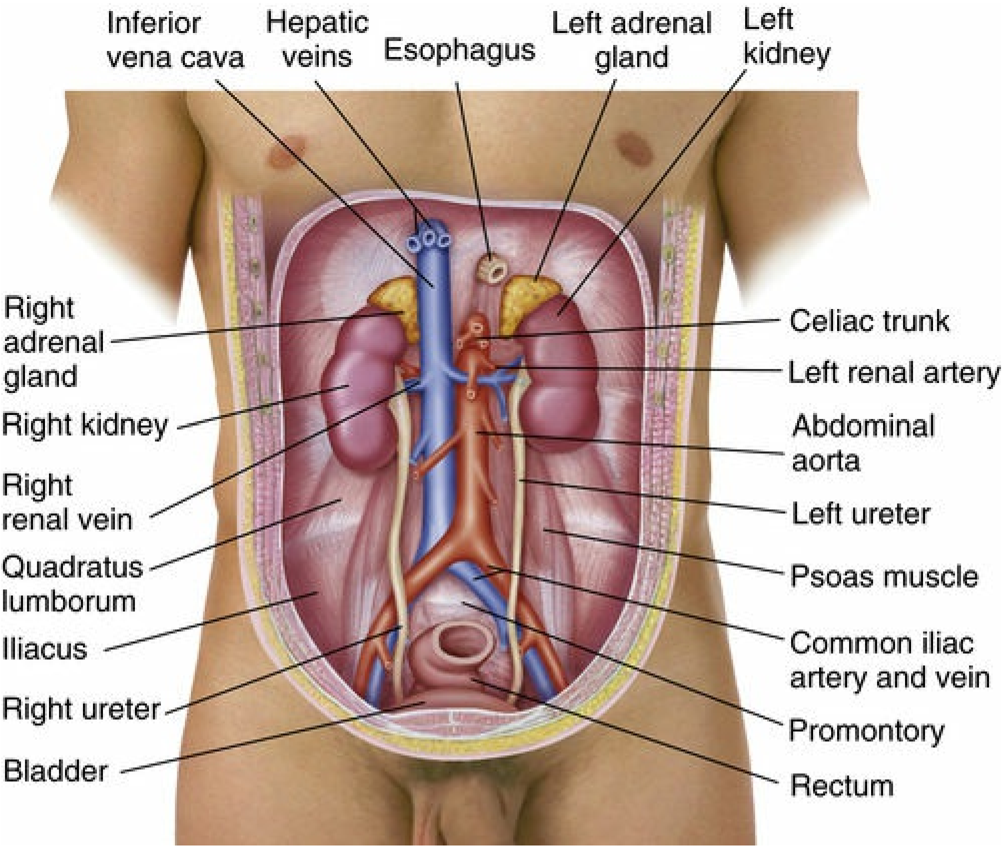

FIGURE 7-12 Location of urinary organs. (From Seidel HM et al: *Mosby's guide to physical examination,* ed 7, St Louis, 2011, Mosby.)

Reproductive System

The male and female sex organs (the testes and ovaries) have two functions: production of gametes (sex cells) and production of hormones. These activities are under the control of tropic hormones from the pituitary gland. Reproductive activity is cyclic in women but continuous in men. The gametes are formed by meiosis. Figures 7-13 and 7-14 illustrate the location of male and female reproductive organs.

Male Reproductive System

In men, spermatozoa develop within the seminiferous tubules of each testis. The interstitial cells between the seminiferous tubules produce testosterone. This male hormone influences sperm cell development and also produces the male secondary sex characteristics such as increased facial hair and body hair as well as voice deepening. Once produced, the sperm are matured and stored in the epididymis of each testis. During ejaculation the pathway for the sperm includes the vas deferens, ejaculatory duct, and urethra. Along the pathway are glands that produce the transport medium or semen. These include the seminal vesicles, prostate gland, and bulbourethral (Cowper's) glands.

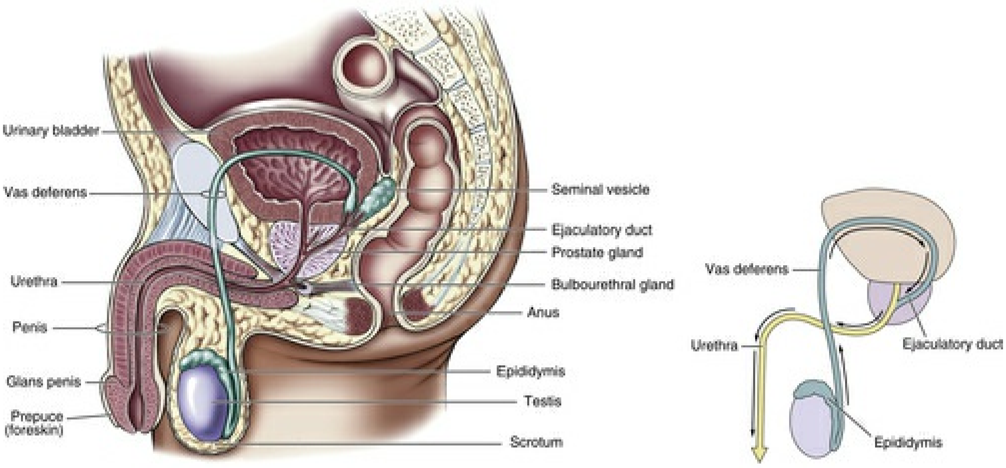

FIGURE 7-13 Male reproductive organs. (From Herlihy: *The human body in health and illness,* ed 5, St Louis, 2014, Saunders.)

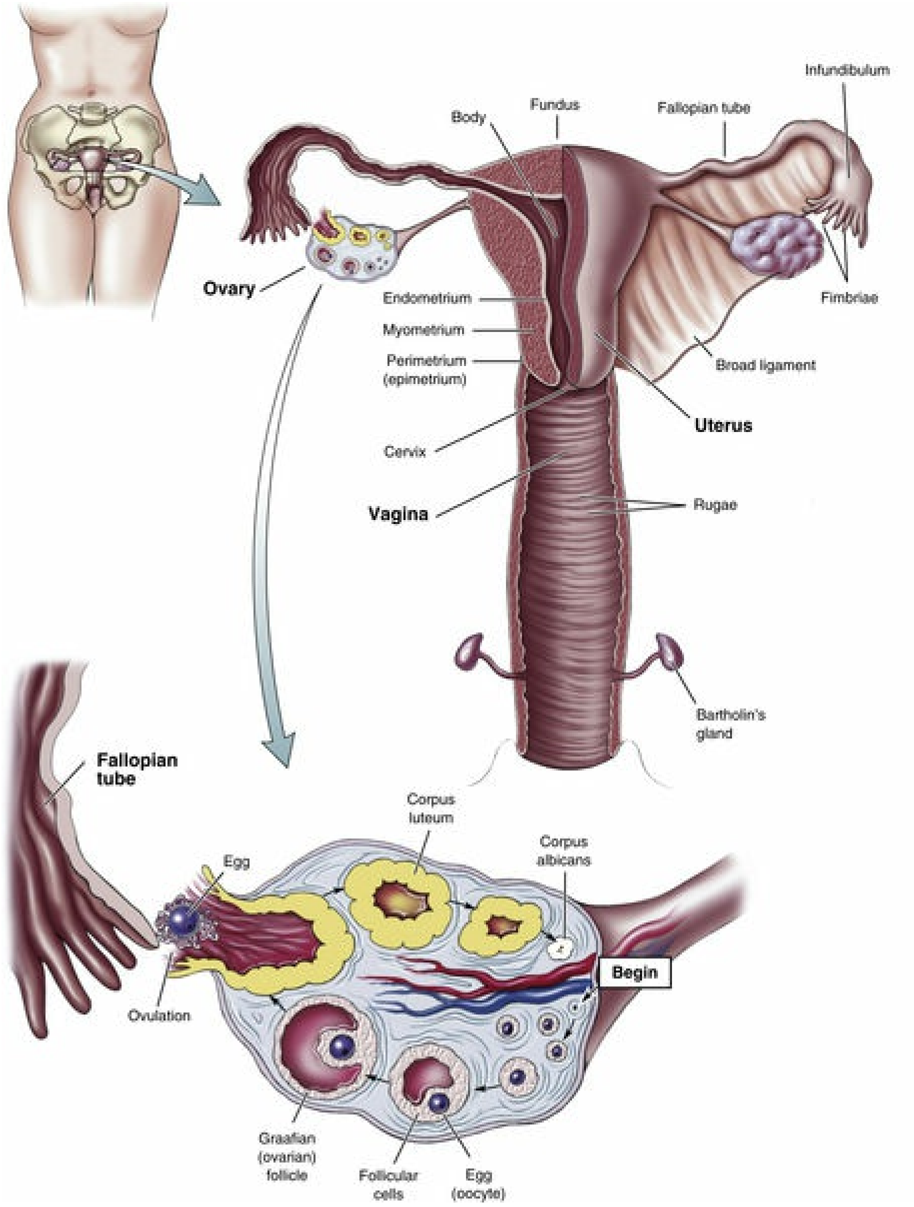

FIGURE 7-14 Female reproductive organs. (From Herlihy: *The human body in health and illness*, ed 5, St Louis, 2014, Saunders.)

Testicular activity is under the control of two anterior pituitary hormones. FSH regulates sperm production. Interstitial cell–stimulating hormone (ICSH) or LH stimulates the interstitial cells to produce testosterone.

Female Reproductive System

In women, each month, under the influence of FSH, several eggs ripen within the ovarian follicles in the ovary. The **estrogen** produced by the follicle initiates the preparation of the endometrium of the uterus for pregnancy. At approximately day 14 of the cycle, a surge of LH is released from the pituitary, which stimulates ovulation and the conversion of the follicle to the corpus luteum. The corpus luteum secretes the hormones **progesterone** and estrogen, which further stimulate development of the endometrium. If fertilization

occurs, the corpus luteum remains functional. If fertilization does not occur, the corpus luteum degenerates and menstruation begins. After ovulation, the egg is swept into the oviduct or fallopian tube. If fertilization occurs, it occurs while the egg is in the oviduct. The fertilized egg or zygote travels to the uterus and implants itself within the endometrium. In the uterus, the developing embryo is nourished by the placenta, which is formed by maternal and embryonic tissues. During pregnancy, hormones from the placenta maintain the endometrium and prepare the mammary glands for breast milk production.

HESI Hint

It might be helpful if you think through the processes such as the menstrual cycle. First, learn the functions of each hormone. Then apply them as you move through the cycle. To better remember the cycles and the hormone actions, have a diagram to examine as you go through the cycle.

Review Questions

1. Which of the following statements is anatomically correct?
   A. The knee is distal to the ankle.
   B. The heart is inferior to the diaphragm.
   C. The hip is proximal to the knee.
   D. The wrist is proximal to the elbow.
2. If you wanted to separate the abdominal cavity from the thoracic cavity, which plane would you use?
   A. Sagittal
   B. Transverse
   C. Frontal
   D. Coronal
3. You have been given a sample of tissue that has pillar-shaped cells arranged tightly together. The tissue you have is:
   A. Squamous epithelium
   B. Cuboidal epithelium
   C. Columnar epithelium
   D. Transitional epithelium
4. The epidermis is classified as a(n):
   A. Cell
   B. Tissue
   C. Organ
   D. System
5. Which type of tissue provides support and structure for the organs?
   A. Epithelial
   B. Connective
   C. Muscle
   D. Nervous
6. Within which epidermal layer of the skin does mitosis occur?
   A. Stratum lucidum
   B. Stratum granulosum
   C. Stratum corneum
   D. Stratum germinativum
7. The orthopedic surgeon informs you that you have broken the middle region of the humerus. What area is he describing?
   A. Epiphysis

B. Articular cartilage
C. Perichondrium
D. Diaphysis

8. Going from superior to inferior, the sequence of the vertebral column is:
A. Sacral, coccyx, thoracic, lumbar, and cervical
B. Coccyx, sacral, lumbar, thoracic, and cervical
C. Cervical, lumbar, thoracic, sacral, and coccyx
D. Cervical, thoracic, lumbar, sacral, and coccyx

9. The cells that form compact bone are called:
A. Osteoclasts
B. Neuroglia
C. Osteoblasts
D. Cancellous

10. Which of the following is true of skeletal muscle? (Select all that apply.)
A. Skeletal muscle comprises 10% of the body's weight.
B. Skeletal muscle attaches to bones by tendons.
C. Muscle contraction helps keep the body warm.
D. Skeletal muscles continuously contract to maintain posture.

11. Which of the following are needed for a muscle cell to contract?
A. Calcium and adenosine diphosphate (ADP)
B. Calcium and adenosine triphosphate (ATP)
C. Potassium and calcium
D. Sodium and calcium

12. If an impulse is traveling from a sense receptor toward the spinal cord, it is traveling along what type of neuron?
A. Motor neuron
B. Sensory neuron
C. Interneuron
D. Bipolar neuron

13. What does the parathyroid hormone regulate?
A. Magnesium
B. Calcium
C. Calcitonin
D. Glucocorticoids

14. Where are the pressoreceptors and chemoreceptors (specialized sensory nerves that assist with the regulation of circulation and respiration) located?
A. Circle of Willis

B. Cerebral arteries
C. Abdominal aorta
D. Carotid body

15. Bile is secreted into which organ?
A. Small intestine
B. Liver
C. Large intestine
D. Stomach

16. What is the role of progesterone in the female reproductive system?
A. Stimulates ovulation
B. Conversion of the follicle to the corpus luteum
C. Stimulates the development of the endometrium
D. Stimulates the start of menstruation

Answers to Review Questions

1. C
2. B
3. C
4. B
5. B
6. D
7. D
8. D
9. C
10. B, C, D
11. B
12. B
13. B
14. D
15. A
16. C

Physics

CHAPTER OUTLINE

KEY TERMS

Acceleration
Average Speed
Binding Energy
Centripetal Acceleration
Force
Friction
Impulse Equation
Joules
Kinetic Energy

Law of Universal Gravitation
Momentum
Newton
Potential Energy
Projectile Motion
Reflection
Refraction
Scalar Quantity
Valence Electrons
Vector Quantity
Velocity

Members of the health professions, particularly medical imaging professionals, use the fundamental principles of physics on a daily basis as they relate to various aspects of imaging science such as radiation safety, radiation dose limits, patient and health professional protection, and patient positioning. Safety and high-quality image production are the goals of all who work within the imaging sciences. Therefore, it is essential that students entering the health professions as medical imaging professionals understand the fundamental principles of physics.

The purpose of this chapter is to review the fundamentals of physics relevant to those considering medical imaging careers. In particular, it is a review of the behavior of matter under various conditions and an understanding of basic phenomena in our natural world. Mastery of these basic principles of physics is an integral step toward a career as a health professional in medical imaging.

Nature of Motion

Speed and Velocity

A study of the behavior of matter begins with an understanding of the nature of motion. The most fundamental concept to comprehend is average speed. **Average speed** is defined as the distance an object travels divided by the time the object travels without regard to direction of travel. This concept is represented mathematically by the following equation, where v_{av} = average speed, d = distance, and t = time:

$$\text{Average speed } (v_{av}) = \frac{\text{Distance}}{\text{Time}} = \frac{d}{t}$$

Sample Problem

1. A car moves for 10 minutes and travels 5,280 meters. What is the average speed of the car?
   A. 528 m/s
   B. 52.8 m/s
   C. 8.8 m/s
   D. 88 m/s

Answer

C—Average speed is the distance an object travels divided by the time the object travels. First, the answers must be expressed in m/s; therefore, the time of travel by the car must be converted from minutes to seconds before the average speed is determined:

$$\frac{x}{10\ \text{min}} = \frac{60\ \text{s}}{1\ \text{min}}$$

$$x = \frac{60\ \text{s} \times 10\ \text{min}}{1\ \text{min}}$$

$$x = 600\ \text{s}$$

Dividing the distance traveled by the car (5,280 meters) by the new value for time traveled by the car (600 seconds) determines that the average speed of the car is 8.8 m/s.

$$\text{Average speed } (v_{av}) = \frac{\text{Distance}}{\text{Time}}$$

$$\text{Average speed} = \frac{5{,}280\ \text{m}}{600\ \text{s}}$$

$$\text{Average speed} = 8.8\ \text{m/s}$$

An important related concept is velocity. **Velocity** refers to speed in a specific direction. Speed is a **scalar quantity** (quantity described simply by a numeric value) and is expressed in units of magnitude. Velocity is a **vector quantity** (quantity describing the time rate of change of an object's position) and must be expressed in both units of magnitude (i.e., speed) and direction of motion.

The average velocity of an object is determined by averaging the initial speed

and the final speed of the object (add the two together and divide by 2). This concept is represented mathematically by the following equation, where v_f = final velocity and v_i = initial velocity.

$$v_{av} = \frac{v_f + v_i}{2}$$

Acceleration

Often, objects in motion change velocity over a period of time. Such a change in motion is called **acceleration** and is defined as the rate of change in velocity over a period of time. Acceleration is a vector quantity and is expressed in terms of magnitude and direction. This concept is represented mathematically by the following equation, where a = acceleration, v_f = final velocity, v_i = initial velocity, and Δt = the change in time.

$$\text{Acceleration}\,(\text{a}) = \frac{\Delta\ \text{Velocity}}{\Delta\ \text{Time}} = \frac{\Delta \text{v}}{\Delta \text{t}} = \frac{\text{v}_\text{f} - \text{v}_\text{i}}{\Delta \text{t}}$$

Sample Problem

2. A cart is set in motion. The cart has an initial speed of 15 m/s and moves for 25 seconds. At the end of 25 seconds, the cart's speed is 40 m/s. What is the magnitude of the cart's acceleration?

   A. 1.0 m/s^2
   B. 2.2 m/s^2
   C. 10.0 m/s^2
   D. 1.1 m/s^2

Answer

A—Acceleration is determined by dividing the change in the cart's velocity (final velocity [40 m/s] – initial velocity [15 m/s] = 25 m/s) by the length of time the cart was in motion (25 seconds), indicating the cart is accelerating at 1.0 m/s^2.

$$\text{Acceleration (a)} = \frac{v_f - v_i}{\Delta t}$$

$$a = \frac{40\text{ m/s} - 15\text{ m/s}}{25\text{ s}}$$

$$a = \frac{25\text{ m/s}}{25\text{ s}}$$

$$a = 1.0\text{ m/s}^2$$

Projectile Motion

The acceleration of objects released above the surface of the earth is influenced by the force of gravity. Gravity, assuming no wind resistance, accelerates an object released above the earth's surface at a rate of 9.8 m/s^2. For example, if a rock is released from rest and falls toward the earth, the speed of the rock will increase by 9.8 m/s for every second the object falls. At the end of 3 seconds the object will have a speed of 29.4 m/s and a velocity of 29.4 m/s in the direction toward Earth's surface.

It is also possible for an object to display two types of motion simultaneously. This motion is generally called **projectile motion.** If a can is kicked from the edge of a cliff, the can will move horizontally at the same time it falls toward Earth (Figure 8-1). The horizontal motion is not an accelerated motion; therefore, horizontal distance (d_x) is a function of velocity (v_x) and time *(t)* based on the following mathematic expression, where the *x* subscript is used to denote motion along the horizontal plane (x axis).

$$d_x = v_x t$$

The vertical motion is more complicated. Gravity is acting vertically, so the velocity along the vertical plane (y axis) is constantly changing. The following mathematic expressions represent several methods of describing vertical motion, where v_f = final velocity, v_i = initial velocity, a = acceleration, d = distance, and t = time.

$$v_f^2 = v_i^2 + 2ad$$
$$d = \frac{1}{2}at^2 + v_i t$$
$$v_f = v_i + at$$

Sample Problem

3. A can is kicked off a cliff that is 19.6 m tall. The horizontal speed given to the can is 12.0 m/s. Assuming there is no air resistance, how far out from the base of the cliff will the can land?

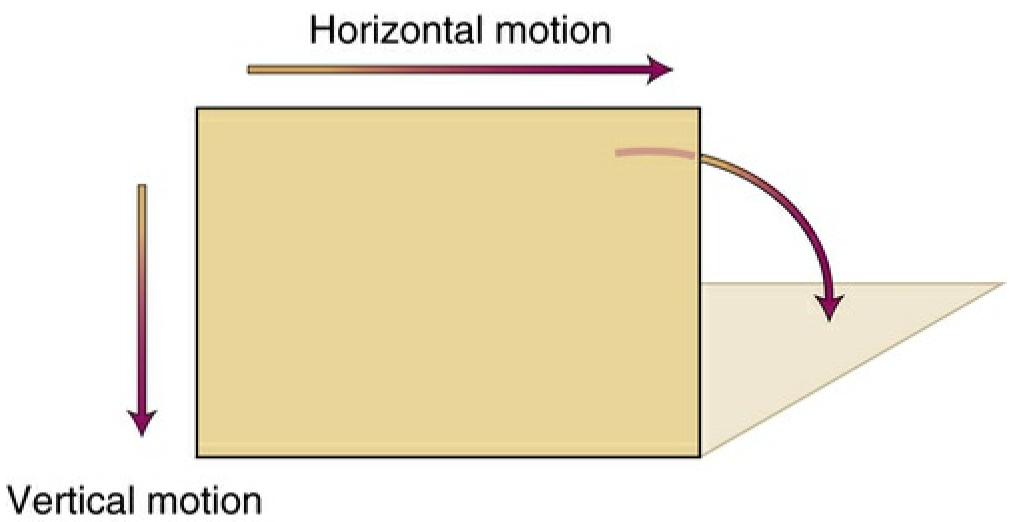

FIGURE 8-1 Projectile motion.

A. 12.0 m
B. 39.2 m
C. 6.0 m
D. 24.0 m

Answer

D—The problem provides values for the vertical distance (height of cliff), vertical acceleration (gravitational constant), and initial vertical velocity (at rest on cliff, thus 0). The first step is to calculate time of flight. The following equation can be transformed to determine the time of flight.

$$d = \frac{1}{2}at^2 + v_i t$$

$v_i t$ drops out of the equation because the initial vertical velocity is 0.

$$d = \frac{1}{2}at^2$$

Convert the equation to solve for time.

$$t = \sqrt{\frac{d}{\frac{1}{2}a}}$$

$$t = \sqrt{\frac{19.6\ \text{m}}{\frac{1}{2}\left(9.8\ \text{m/s}^2\right)}}$$

$$t = 2.0\ \text{s}$$

Once the time of flight is determined, insert the appropriate values into the horizontal distance equation to solve for horizontal distance.

$$d_x = v_x t$$
$$d_x = 12\ \text{m/s} \times 2\ \text{s}$$
$$d_x = 24\ \text{m}$$

Assuming no air resistance, the can will land 24.0 m from the cliff.

Newton's Laws of Motion

Before delving into Newton's laws of motion, a brief discussion of force is necessary. **Force** is defined as a push or pull on an object. When two forces are equal in magnitude and in opposing directions, they cancel each other out and result in a balanced force. However, if one of the two forces is greater than the other, an unbalanced force exists and with it acceleration. Net force is simply the sum of the individual forces acting on an object. Keep in mind that the + and − signs are used to indicate direction of force and the mathematic rules associated with summing negative and positive numbers apply.

Newton's First Law of Motion

Newton's first law of motion states that a body at rest will remain at rest, and a body in motion will remain in motion with a constant velocity, unless acted on by an unbalanced force (a force not opposed by one of equal magnitude and in the opposite direction). Newton's second law of motion states that an unbalanced force will cause acceleration, and this acceleration is directly proportional to the unbalanced force. This relationship is expressed mathematically as follows, where F = force, a = acceleration, and k = the constant of proportionality.

$$F = ka$$

Newton's Second Law of Motion

When used in Newton's second law of motion, the constant of proportionality *(k)* is equal to the mass of the object. Therefore, Newton's second law is expressed mathematically as follows, where F = force, m = mass, and a = acceleration.

$$F = ma$$

Sample Problem

4. A box rests on a tabletop. The box has a mass of 25 kg and is acted on by two forces. The force pushing to the right is 96 N, whereas the force pushing to the left is 180 N. Determine the magnitude of the acceleration of the box, assuming there is no friction between the box and the table.

   A. 11.0 m/s^2
   B. 3.4 m/s^2
   C. 5.5 m/s^2
   D. 7.2 m/s^2

Answer

B—To determine the acceleration of the box, it is necessary to first determine the net force acting on the box. Remember that the net force acting on the box is simply the sum of all forces acting on the box. Because the two forces are opposing each other, one force is considered a positive force and the other a negative force. Therefore, net force is represented by the following mathematic equation and is determined to be 84 N to the left.

$$\text{NetForce} = F_{\text{left}} + (-)\ F_{\text{right}}$$
$$\text{NetForce} = 180\ \text{N} + (-)\ 96\ \text{N}$$
$$\text{NetForce} = 84\ \text{N} \leftarrow$$

Once the net force is determined, use Newton's second law equation to determine the magnitude of acceleration of the box.

$$F = ma$$

First, convert the formula to solve for acceleration.

$$a = \frac{F}{m}$$
$$a = \frac{84\ \text{N}}{25\ \text{kg}}$$

The acceleration of the box is determined to be 3.4 m/s^2. NOTE: Newtons are also expressed in kg-m/s^2.

If the mass is expressed in kilograms and the acceleration is expressed in meters per second squared (m/s^2), the unit of force is referred to as the **newton** (N) and is equal to the force necessary to accelerate a mass of one kilogram one meter per second per second. Weight is simply a specialized case of Newton's second law. Weight can be stated mathematically as follows, where *m* = mass in kilograms and *g* = 9.8 m/s^2 (i.e., the rate of acceleration associated with gravity).

$$W = mg$$

Sample Problem

5. An object has a mass of 1,250 g. Determine the weight of the object on Earth.
   A. 12,250 N
   B. 122.50 N
   C. 1,225.0 N
   D. 12.25 N

Answer

D—To determine the weight of the object on Earth, first convert the units of mass to kilograms (1,250 g = 1.25 kg). Second, insert the appropriate values into the weight equation.

$$W = mg$$
$$W = 1.25\text{ kg} \times 9.8\text{ m/s}^2$$
$$W = 12.25\text{ N}$$

The weight of the object on Earth is determined to be 12.25 N.

Newton's Third Law of Motion

Newton's third law of motion states that for every action there must be an equal and opposite reaction.

Friction

Friction is a force that opposes motion and is expressed in newtons. If a box (Figure 8-2) is slid on a surface at a constant rate by an applied force, we can deduce that friction is present and is opposing the motion of the box. Because there is no acceleration of the box, it is clear that friction is present and all forces are balanced. This relationship of balanced forces is represented in the diagram. Note that the normal force *(A)* and the weight *(B)* are balanced. The applied force *(C)* is to the right and has a magnitude of 100 N. The frictional force *(D)* is to the left and must also be 100 N if the box has no acceleration.

Sample Problem

6. A crate is pulled to the right by a rope attached to the crate. The force applied to the rope is 600 N. As the crate slides along the floor, there is a frictional force between the crate and the floor that has a magnitude of 450 N. Determine the magnitude of the net force acting on the crate.
   A. 1,050 N
   B. 600 N
   C. 150 N
   D. 450 N

Answer

C—To determine the magnitude of the net force acting on the crate, remember that the magnitude of the net force acting on the box is simply the sum of all forces acting on the box. Because the two forces are opposing each other, applied force to the right and friction to the left, the magnitude of the net force is represented by the following mathematic equation and is determined to be 150 N to the right.

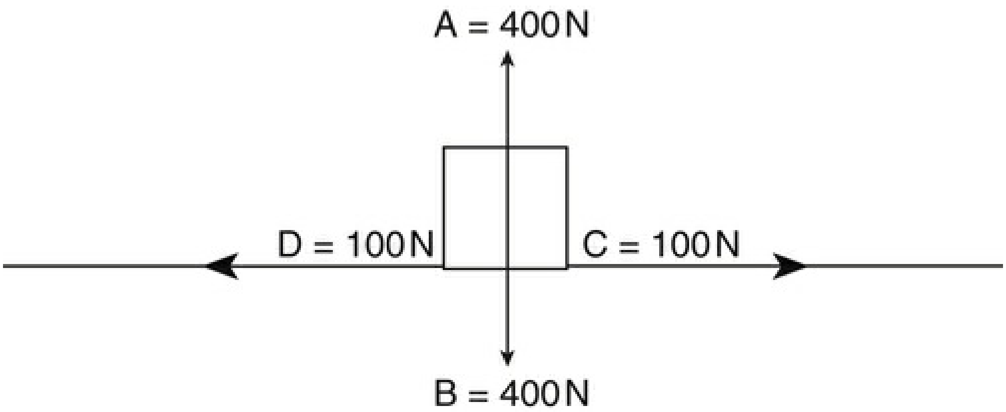

FIGURE 8-2 Depiction of a box being slid on a surface at a constant rate by an applied force.

$$\text{NetForce} = F_{right} + (-)\ F_{left}$$

$$\text{NetForce} = 600\ \text{N} + (-)\,450\ \text{N}$$

$$\text{NetForce} = 150\ \text{N} \rightarrow$$

Rotation

In addition to displaying linear motion, an object may display a rotating or circular motion. The relationship between the angular displacement and the radius of the circle is expressed mathematically as follows, where θ = the angular displacement, S = arc length, and r = radius of the circle through which the object is moving.

$$\theta = \frac{S}{r}$$

The average speed of the circular motion can be described by looking at the number of rotations or revolutions an object makes in a given time. The angular speed is the number of radians completed in a given time unit. This is expressed mathematically as follows, where ω = angular speed, θ = the angular displacement, and t = time. When the mathematic expression is considered, it is important to remember that there are 2π radians in one revolution.

$$\omega = \frac{\Delta\theta}{\Delta t}$$

It is also possible to have an angular acceleration as a spinning or rotating object gains or loses speed. This is expressed mathematically as follows, where α = angular acceleration, ω = angular speed, and t = time.

$$\alpha = \frac{\Delta\omega}{\Delta t}$$

The relationship between linear motion and rotational motion is analogous and conforms to Newton's laws. Box 8-1 provides a description of the relationship between the mathematic expressions describing linear motion and those describing rotational motion. Beside each linear motion formula is its rotational motion counterpart. The expressions have been defined and applied within this chapter.

Box 8-1 Mathematic Expressions Describing Linear

and Rotational Motion

Linear Motion	Rotational Motion
$d = v_{av}t$	$\theta = \omega_{av}t$
$v_f = v_i + at$	$\omega_f = \omega_i + \alpha t$
$d = \frac{1}{2}at^2 + v_i t$	$\theta = \frac{1}{2}\alpha t^2 + \omega_i t$
$v_f^2 = v_i^2 + 2ad$	$\omega_f^2 = \omega_i^2 + 2\alpha\theta$

Sample Problem

7. If a bicycle wheel goes from 48 revolutions per second to 84 revolutions per second in 11 seconds, what is the angular acceleration of the wheel?

A. 3.27 revolutions/s^2
B. 6.00 revolutions/s^2
C. 12.0 revolutions/s^2
D. 1.64 revolutions/s^2

Answer

A—To determine the angular acceleration, divide the change in angular speed by the time it took to complete the change in speed.

$$\omega_f = \omega_i + \alpha t$$

Convert the equation to solve for angular acceleration *(a).*

$$\alpha = \frac{\omega_f - \omega_i}{t}$$

$$\alpha = \frac{84 \text{ rev/s} - 48 \text{ rev/s}}{11 \text{ s}}$$

$$\alpha = 3.27 \text{ rev/s}^2$$

Uniform Circular Motion

It is possible for an object to experience acceleration even though the object is moving at a constant speed. This is possible because acceleration is a vector quantity and is defined as a change in velocity over a change in time. Velocity has a magnitude and a direction, so even though the speed or magnitude of the velocity is constant, the direction could be changing. In uniform circular motion, this is exactly what is happening. Therefore, the object is undergoing an acceleration called a **centripetal acceleration** (rotational motion equivalent of acceleration). Centripetal acceleration is represented mathematically as follows, where a_c = centripetal acceleration, v = the speed of the object in meters per second, and r = the radius of the circle.

$$a_c = \frac{v^2}{r}$$

Because there is a centripetal acceleration, there must also be a centripetal force. Newton's law states that force is a function of mass and acceleration; therefore, centripetal force must be a function of mass of an object and centripetal acceleration. This relationship is expressed mathematically as follows, where F_c = centripetal force, m = the mass of the object, v = the velocity, and r = the radius of the circle.

$$F_c = \frac{mv^2}{r}$$

The direction of both the force and the acceleration must be toward the center of the circle. Think of whirling a stone attached to a string in a horizontal circle. The tension in the cord keeps the stone moving in a circular path by pulling inward on the stone.

Sample Problem

8. A 0.6-kg rock is spun in a circle on a 1.2-m string. If the string breaks at 15 N of tension, how fast must the rock be moving?

   A. 30 m/s
   B. 6 m/s
   C. 5 m/s
   D. 5.5 m/s

Answer

D—The centripetal force (15 N) is supplied by the tension in the string. The radius of the circle is 1.2 m, and the mass of the rock is 0.6 kg. After these values are inserted in the centripetal force equation, the speed of the stone is determined to be 5.5 m/s.

$$F_c = \frac{mv^2}{r}$$

Convert the equation to solve for velocity.

$$v = \sqrt{\frac{F_c r}{m}}$$

$$v = \sqrt{\frac{(15\ \text{N})\ (1.2\ \text{m})}{0.6\ \text{kg}}}$$

$$v = 5.5\ \text{m/s}$$

Kinetic Energy and Potential Energy

Kinetic energy of an object is the energy resulting from the motion of the object and is represented by the following equation, where *KE* = kinetic energy, *m* = mass of the object, and *v* = velocity.

$$KE = \frac{1}{2} mv^2$$

In this equation, mass must be expressed in kilograms and velocity must be expressed in meters per second.

The **potential energy** of an object is the energy the object has because of its position and is expressed by the following equation, where *PE* = potential energy, *m* = mass of the object, *g* = acceleration caused by gravity, and *h* = the height at which the object is located above the ground.

$$PE = mgh$$

In this equation, mass must be expressed in kilograms, gravity is a constant expressed as 9.8 m/s^2, and height is expressed in meters.

Kinetic energy and potential energy are scalar quantities and are expressed in units called **joules.** A joule is a newton-meter or a kilogram-meter squared per second squared ($kg\text{-}m^2/s^2$). Remember that the law of conservation of energy states that energy must be conserved; therefore, kinetic energy and potential energy can be interchanged if we assume that there is no friction or air resistance present.

Sample Problem

9. A car has a mass of 1,100 kg and is moving at 24 m/s. How much kinetic energy does the car have as a result of its motion?

A. 26,400 J
B. 13,200 J
C. 633,600 J
D. 316,800 J

Answer

D—The problem provides values for mass and velocity; after the appropriate values for kinetic energy are inserted into the equation, the kinetic energy as a result of the car's motion is determined to be 316,800 J.

$$KE = \frac{1}{2}mv^2$$

$$KE = \frac{1}{2}(1{,}100 \text{ kg})\ (24 \text{ m/s})^2$$

$$KE = 316{,}800 \text{ J}$$

Linear Momentum and Impulse

Considering Newton's second law of motion in the following slightly different form allows for the development of a new relationship.

$$F = \frac{m\Delta v}{\Delta t}$$

If both sides of this equation are multiplied by Δt, a new relationship between force and time is established and expressed as follows:

$$F\Delta t = m\Delta v$$

The new relationship is referred to as the **impulse equation** because a force applied over a period of time is an impulse. This impulse causes a change in velocity of the object, which results in a change in momentum of the object. **Momentum** is defined as the amount of motion displayed by an object and is represented by the following mathematical equation, where p = the momentum in kilograms-meters per second, m = the mass in kilograms, and Δv = the change in velocity of the object.

$$p = m\Delta v$$

Momentum is a vector quantity, which means we must have both magnitude and direction to completely express momentum. Momentum must always be conserved, so the momentum before an interaction must equal the momentum after an interaction. This relationship is expressed mathematically as follows, where m_1 and m_2 = masses 1 and 2, v_1' and v_2' = the initial velocities of objects 1 and 2, and v_1 and v_2 = the final velocities of objects 1 and 2 after the interaction.

$$m_1 v_1' + m_2 v_2' = m_1 v_1 + m_2 v_2$$

Sample Problem

10. A 30-g rubber ball traveling at 1.60 m/s strikes a motionless 400-g block of wood. If the ball bounces backward off the block of wood at 1.00 m/s, how fast will the block of wood be moving?

A. 0.045 m/s
B. 0.195 m/s
C. 0.60 m/s
D. 1.00 m/s

Answer

A—With the conservation of momentum equation, with the rubber ball established as mass 1 and the block of wood as mass 2, and with the initial velocity of the block of wood being 0, the speed of the block of wood after impact with the ball is determined to be 0.045 m/s.

$$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$$

Convert the equation to solve for the speed of the block after impact *(v_2')*.

$$v_2' = \frac{m_1v_1 + m_2v_2 - m_1v_1'}{m_2}$$

$$v_2' = \frac{(30\ \text{g} \times 1.60\ \text{m/s}) + (400\ \text{g} \times 1.60\ \text{m/s}) - 30\ \text{g} \times 1.0\ \text{m/s}}{400\ \text{g}}$$

$$v_2' = 0.045\ \text{m/s}$$

Universal Gravitation

Newton stated that every object in the universe attracts every other object in the universe. This statement is known as the **law of universal gravitation** and is expressed mathematically as follows, where F = force of attraction, m_1 and m_2 = the masses of objects 1 and 2 expressed in kilograms, G = the universal gravitation constant (6.67×10^{-11} Nm^2/kg^2), and r = the distance between the two objects expressed in meters.

$$F = \frac{G m_1 m_2}{r^2}$$

Sample Problem

11. If object 1 of mass 860 kg is placed 300 m from object 2 of mass 650 kg, what force of attraction exists between the two objects?

A. 1.24×10^{-7} N
B. 2.48×10^{-7} N
C. 4.14×10^{-10} N
D. 8.28×10^{-10} N

Answer

C—When all values are correctly placed in the universal gravitation equation, the force of attraction between the two masses is determined to be 4.14×10^{-10} N.

$$F = \frac{Gm_1 m_2}{r^2}$$

$$F = \frac{(6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2)\ (860\ \text{kg})\ \ (650\ \text{kg})}{(300\ \text{m})^2}$$

$$F = \frac{0.0000372853\ \text{Nm}^2}{90{,}000\ \text{m}^2}$$

$$F = 4.14 \times 10^{-10}\ \text{N}$$

Waves and Sound

To review waves, it is helpful to take a look at the vocabulary associated with waves in Box 8-2 and the illustration in Figure 8-3.

The frequency of the wave and the period of the wave are inversely related and expressed mathematically as follows, where f = the frequency and T = the period.

$$f = \frac{1}{T}$$

and

$$T = \frac{1}{f}$$

Waves are produced by objects that vibrate or show simple harmonic motion. A wave is a disturbance or pulse that travels through a medium or space. Waves are carriers of energy that travel in the form of light, sound, microwaves, ultraviolet light, x-rays, gamma rays, television, and radio. There are two types of waves, mechanical and electromagnetic.

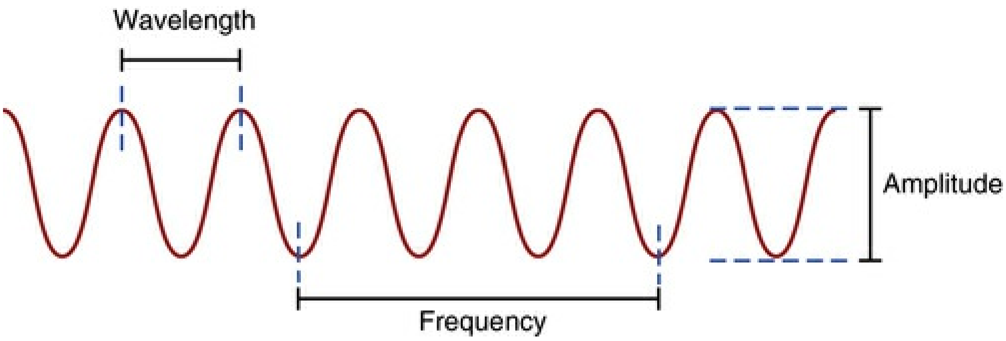

FIGURE 8-3 Components of a wave. (From Johnston JN, Fauber TL: *Essentials of radiographic physics and imaging,* ed. 2, St. Louis, 2016, Elsevier Mosby.)

Box 8-2 Wave Vocabulary

Crest: High point of a wave.
Trough: Low point of a wave.

Amplitude: Maximum displacement from equilibrium.
Wavelength: Distance between successive identical parts of a wave.
Frequency: Vibrations or oscillations per unit of time (number of waves per unit time). Frequency is expressed in vibrations per second and is measured in hertz (s^{-1}).

Mechanical Waves

Each type of mechanical wave is associated with some material or substance called the *medium* for that type. As the wave travels through the medium, the particles that make up the medium undergo displacements of various kinds, depending on the nature of the wave. Examples of these would be sound, water, and seismic.

Electromagnetic Waves

Electromagnetic waves do not require a medium for transmission. These waves are produced by electricity and magnetism and make up the electromagnetic spectrum. They are pure energy and travel as electric and magnetic disturbances in space (Figure 8-4). These waves all travel at the speed of light (3×10^8 m/s). The components of the electromagnetic spectrum are radio waves, microwaves, infrared light, visible light, ultraviolet light, x-rays, and gamma rays.

Classification of Waves

Waves are classified by the way they displace matter or how they cause matter to vibrate. The wave is either transverse or longitudinal in nature. Transverse waves cause the particles of the medium to vibrate perpendicular to the direction the wave travels. Longitudinal or compressional waves cause the particles of the medium to vibrate parallel to the direction of the wave. With both longitudinal and transverse waves, the particles of the medium vibrate but *do not* travel with the wave. Longitudinal waves require a medium to be transmitted. The speed at which a wave travels through a medium is determined by the frequency and the wavelength of the wave. This relationship is expressed mathematically as follows, where f = frequency and λ = the wavelength.

$$\text{Speed} = f\lambda$$

The amplitude of a wave is proportional to the potential energy content of the wave. Therefore, the higher the wave, the greater the stored energy it is carrying. The higher the frequency, the more kinetic energy the wave possesses because speed (v) = $f\,\lambda$ and KE = $\frac{1}{2}\,mv^2$.

When a string is plucked, a wave will reflect back and forth from one end of the string to the other, creating nodes and antinodes. This is called a *standing wave* because it appears to stand still. Nodes are points along the standing wave that remain stationary. Antinodes are points of maximum energy where the largest amplitude occurs along the standing wave. The frequency at which the string vibrates depends on the number of antinodes, the wave speed, and the length of the vibrating string. Mathematically this relationship is expressed as follows:

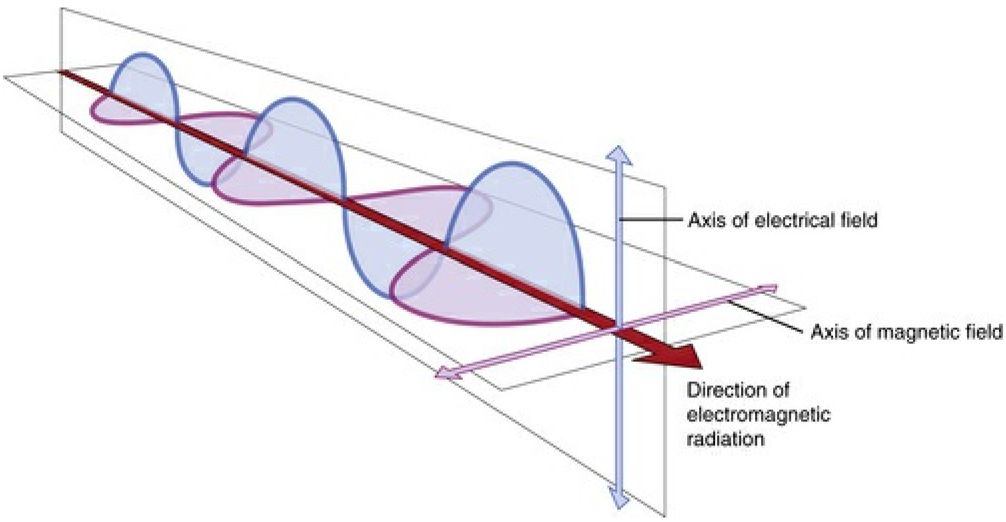

FIGURE 8-4 Electromagnetic radiation is an electric and magnetic disturbance in space. (From Johnston JN, Fauber TL: *Essentials of radiographic physics and imaging,* ed. 2, St. Louis, 2016, Elsevier Mosby.)

$$\text{Frequency} = \frac{(\text{Number of antinodes})(\text{Wave speed})}{2\,(\text{Length})} = \frac{nv}{2L}$$

Sample Problem

12. A wave in a string travels at 24 m/s and has a wavelength of 0.90 m. What is the frequency?
   A. 2.67 Hz
   B. 26.67 Hz
   C. 1.33 Hz
   D. 13.33 Hz

Answer

B—To determine the frequency of a wave given the speed and wavelength, simply divide the speed of the wave by the wavelength. After insertion of the appropriate values in the following equation, the frequency of the wave is determined to be 26.67 Hz.

$$\text{speed} = f\lambda$$

Convert the equation to solve for frequency *(f)*.

$$f = \frac{\text{speed}}{\lambda}$$

$$f = \frac{24\ \text{m/s}}{0.9\ \text{m}}$$

$$f = 26.67\ \text{Hz}$$

HESI Hint

Medical imaging, whether radiography, magnetic resonance imaging (MRI), or ultrasound, deals with electromagnetic waves/energies. An understanding of their nature and physical attributes is essential to competent practice as a medical imaging professional.

Light

Light is an electromagnetic wave that travels at 3.0×10^8 m/s. Light needs no medium through which to travel and is a result of electric and magnetic interactions. Light exhibits properties of both a wave and a particle. When light interacts with a medium, it does so at the atomic level. The light energy is absorbed by the electrons of the atoms, causing them to vibrate. This excess energy may be absorbed by the medium and converted to heat. It may also be reflected or it may be transmitted (pass through with some refraction or bending). For example, when light traveling through air reaches a mirror, the mirror constitutes a new boundary, a transition from one medium (air) to another (glass mirror). At this boundary, some of the light energy will be reflected and some will be transmitted into this new medium. We are mainly interested in two properties of light: reflection and refraction.

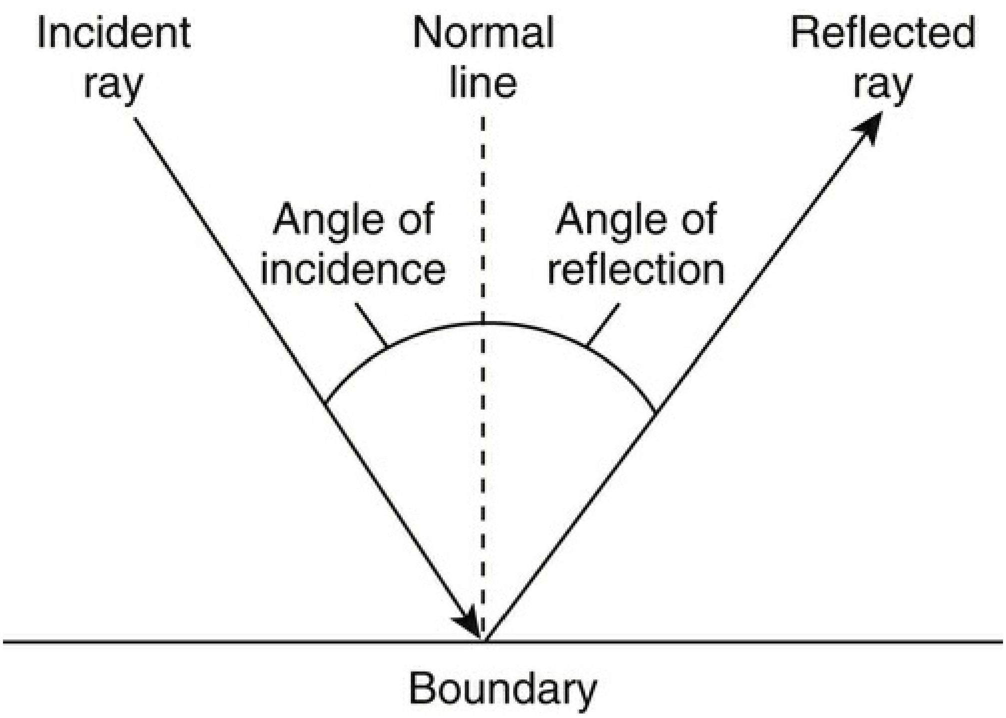

FIGURE 8-5 Reflection is a wave bouncing back from a barrier or from a boundary between two media.

Reflection is the bouncing back of a wave from a barrier or from a boundary between two media, as depicted in Figure 8-5. There are a few terms important to the discussion of reflection. Incident wave is the wave that strikes the barrier (or boundary). *Reflected wave* is the wave that bounces off and leaves the barrier. The *normal line* is a reference line that is drawn perpendicular to a barrier. The *angle of incidence* is the angle between the normal line and the incident wave. The *angle of reflection* is the angle between the normal line and the reflected wave. Applying the mirror example to Figure 8-5, the mirror would be the

boundary, the incident ray would be the light traveling to the mirror, and the reflected ray would be the light traveling way from the mirror. The law of reflection states that when a wave disturbance is reflected at a boundary of a transmitting medium, the angle of incidence must equal the angle of reflection.

HESI Hint

X-rays and gamma rays also exhibit properties of both a wave and a particle referred to as *wave/particle duality.* Understanding this property aids in understanding how these radiant energies interact with matter.

Refraction is the bending of a wave as it passes at an angle from one medium into another if the speed of propagation differs. That is, refraction is caused by the change in speed of a wave as it transitions from one medium to the next. Figure 8-6 depicts a light ray as it passes from air into a container of water. Different media have different speeds of propagation, so light travels at different speeds through different media. Which way light will refract relative to normal depends on whether the wave is transitioning to a faster or slower medium. As a wave moves from one medium into an optically denser medium (from a faster medium to a slower medium), the wave bends toward the normal. As a wave moves from a medium into an optically less dense medium (from a slower medium to a faster medium), the wave bends away from the normal.

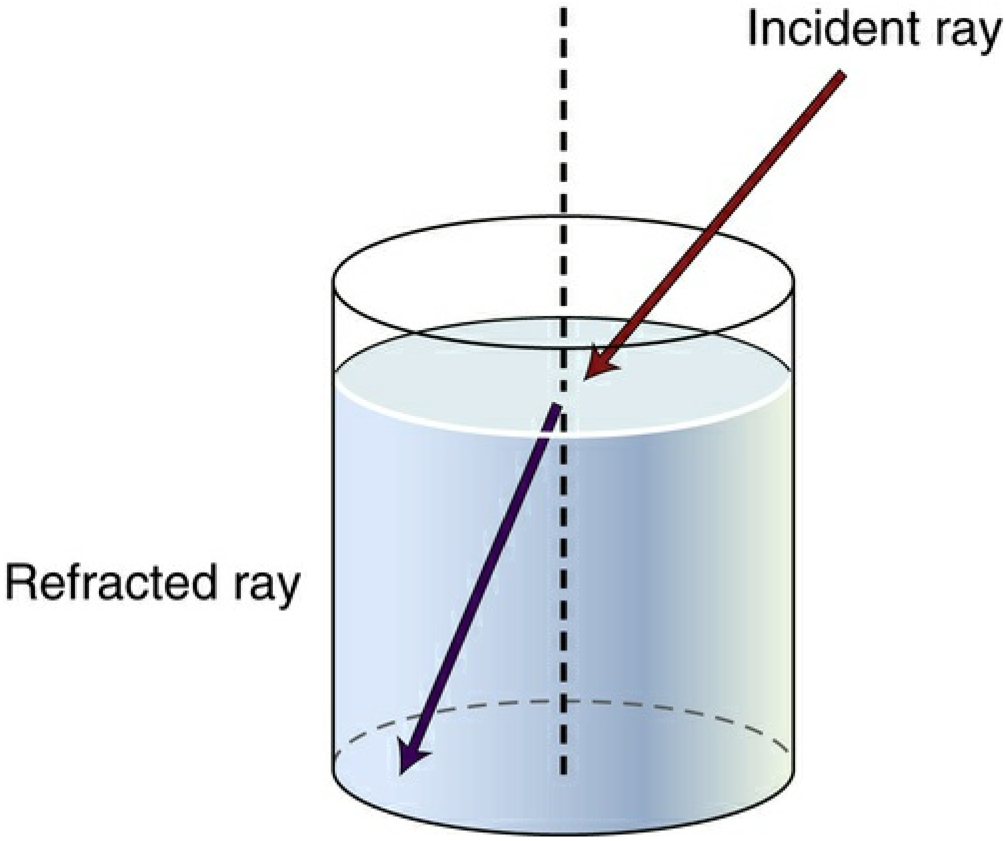

FIGURE 8-6 Light ray refracted in a container of water.

The mathematic relationship for this behavior is called *Snell's law*, which is expressed mathematically as follows, where n = the index of refraction and θ = the angle of refraction.

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

The index of refraction is a ratio of the speed of light in a vacuum to the speed of light in a given material. This mathematic relationship is expressed as follows, where c = the speed of light in a vacuum (3×10^8 m/s) and v_s = the speed of light in a given substance.

$$n = \frac{c}{v_s}$$

Sample Problem

13. If the index of refraction for quartz is 1.46, what is the speed of light in quartz?

A. 2.05×10^8 m/s
B. 4.38×10^8 m/s
C. 1.25×10^8 m/s
D. 0.489×10^8 m/s

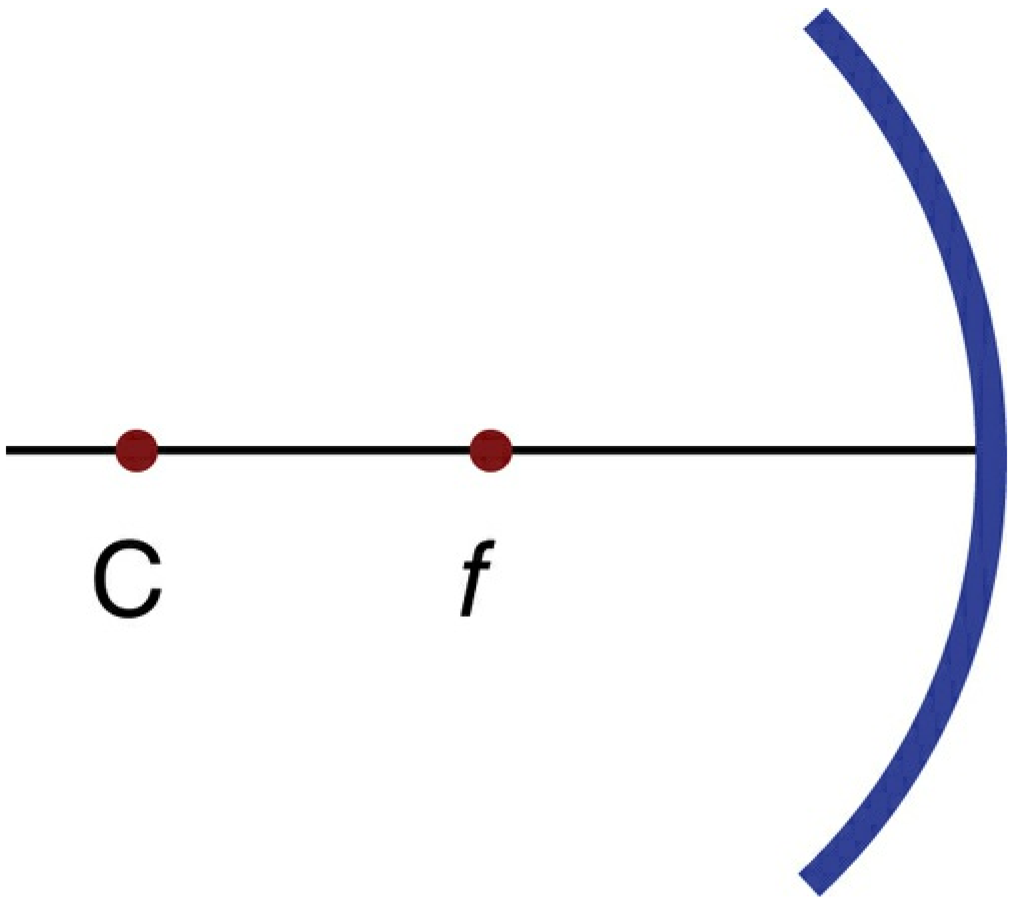

FIGURE 8-7 Concave mirror.

Answer

A —To determine the speed of light in quartz, divide the speed of light by index of refraction for quartz. Through use of the following equation, the speed of light in quartz is determined to be 2.05×10^8 m/s.

$$n = \frac{c}{v_s}$$

Convert the equation to solve for speed of light in a substance *(v_s)*.

$$v_s = \frac{3 \times 10^8 \text{ m/s}}{1.46}$$

$$v_s = 2.05 \times 10^8 \text{ m/s}$$

Optics

The previous discussion of reflection assumed a plane mirror. However, the shape of the mirror, specifically with spherical mirrors (i.e., convex or concave), changes the direction of reflection. Concave mirrors have positive focal lengths, whereas convex mirrors have negative focal lengths. Concave mirrors form a variety of image shapes, sizes, and orientations, depending on the focal length of the mirror and where the object is placed. Figure 8-7 depicts a concave mirror with the focal point *(f)* and curvature *(C).* With the object beyond the center of curvature *(C),* we have an image that is smaller than the object and inverted in orientation. If we place the object at *C,* the resulting image is the same size as the object and inverted in orientation. If the object is between *C* and the focal point *(f),* the image is larger than the object and inverted in orientation. If the object is at *f,* there is no image formed. If the object is between *f* and the mirror, the image is upright and larger in size and virtual. Convex mirrors can form only images that are smaller and upright. Real images are always inverted, and virtual images are always upright.

Lenses form images by refraction. There are two basic types of lenses: convex (converging) and concave (diverging). Convex lenses always have positive focal lengths, and concave lenses always have negative focal lengths. Convex lenses can form a variety of image shapes, sizes, and orientations, depending on the focal length of the lens and the object's position. When an object is placed at a position greater than *2f,* the image is reduced, inverted, and on the opposite side of the lens. The placement of an object at *2f* results in an image that is the same size as the object, inverted, and on the opposite side of the lens. The placement of an object between *2f* and *f* results in an image that is larger than the object, inverted, and on the opposite side of the lens. When the object is placed at *f,* no image is formed. If the object is between *f* and the lens, the image is upright, larger, and on the same side of the lens. A concave lens can form only an image that is upright and smaller than the object.

Atomic Structure

Many discussions of physical principles are aided by an understanding of basic atomic structure. The atom is composed of three fundamental particles: protons, neutrons, and electrons (Figure 8-8). Protons are one part of the nucleus of the atom and carry one unit of positive electric charge. Neutrons are the other principal part of the nucleus and are electrically neutral. Electrons orbit the nucleus in specific energy levels and carry one unit of negative electric charge. The energy levels or shells in which the electrons orbit are lettered beginning with "k" (i.e., k, l, m, n, o, etc.). The closer the electron shell, the stronger the **binding energy** (how tightly the electron is bound to the nucleus). Each shell holds a specific number of electrons. This number may be found using the following formula, where *n* is the shell number (k = 1, l = 2, m = 3, and so on):

$$2n^2$$

When the number of positive charges (protons in the nucleus) equals the number of negative charges (electrons in orbit), the atom is said to be stable.

HESI Hint

A solid understanding of the atom and atomic structure is key to understanding x-ray production, radiation dose, image production, and many other fundamental principles of medical imaging.

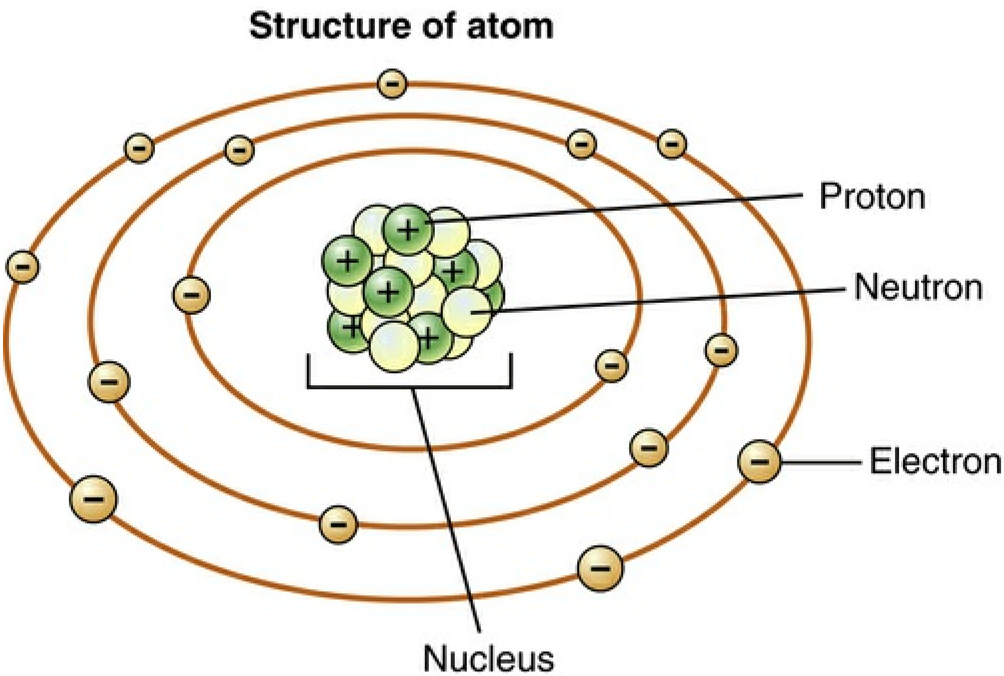

FIGURE 8-8 Basic atomic structure. (From Johnston JN, Fauber TL: *Essentials of radiographic physics and imaging,* ed. 2, St. Louis, 2016, Elsevier Mosby.)

The Nature of Electricity

The electric property of a given material depends on the nature of its atoms. Materials whose atoms have loosely bound **valence electrons** (electrons in the outermost shell) are good conductors of electricity. Conversely, materials whose valence electrons are tightly bound are good electric insulators. Because the protons (positive charges) of an atom are tightly bound in the nucleus of the atom and not free to move about, most discussions of the flow of electricity involve negative charges (electrons).

Coulomb's Law

There are two types of basic electric charge: positive and negative. The smallest unit of positive charge rests with the proton and the smallest unit of negative charge rests with the electron. Like charges will repel each other, whereas opposite charges will attract. This force of attraction or repulsion is expressed by Coulomb's law, which states that the force of attraction or repulsion between two charged objects is directly proportional to the product of their quantities and inversely proportional to the square of the distance between them. The unit of measure for electric charge is the coulomb. The force of attraction or repulsion is determined by the mathematic relationship expressed by Coulomb's law, where k = a constant (9×10^9 N-m^2/C^2), q_1 and q_2 = the charges on objects 1 and 2 expressed in coulombs, and r = the distance between the two charged objects in meters.

$$F = \frac{k\, q_1\, q_2}{r^2}$$

Sample Problem

14. An object of charge 16 μC is placed 50 cm from an object of charge 30 μC. What is the magnitude of the resulting force between the two objects?

A. 17.28 N
B. 8.64 N
C. 1.73×10^{13} N
D. 8.64×10^{12} N

Answer

A—To solve this problem use Coulomb's law. First, convert μC to C, remembering that 1μC is 1×10^{-6} C, and convert the distance from centimeters to meters. After insertion of the correct values into the equation, remembering to square the distance (r^2), the force between the two objects is determined to be 17.28 N.

$$F = \frac{k\, q_1\, q_2}{r^2}$$

$$F = \frac{\left(9 \times 10^9\ \mathrm{N-m^2/C^2}\right)\ (16 \times 10^{-6}\ \mathrm{C})\ (30 \times 10^{-6}\ \mathrm{C})}{(0.5\ \mathrm{m})^2}$$

$$\mathrm{F} = \frac{\left(9 \times 10^9\ \mathrm{N-m^2/C^2}\right)\ (16 \times 10^{-6}\ \mathrm{C})\ (30 \times 10^{-6}\ \mathrm{C})}{(0.5\ \mathrm{m})^2}$$

$$\mathrm{F} = 17.28\ \mathrm{N}$$

Electric Fields

An electric field exists around charged objects. This field force created by the charged object is basically a change in the space that surrounds the charged object. One way to test the nature of this electric field is to use a positive test charge. If the electric field is generated by a negative charge, the test charge will experience an attractive force. If the electric field is generated by a positive charge, the test charge will experience a repulsive force. Owing to these interactions, scientists have defined the direction of an electric field to be away from a positive charge and toward a negative charge. The magnitude of an electric field is stated mathematically as follows, where E = the magnitude of the electric field, F = the force a test charge would experience, and q_o = the magnitude of the test charge.

$$E = \frac{F}{q_o}$$

Because electric fields are vector quantities, they should be treated as such. The direction of an electric field is defined as the direction a positive test charge would be moved when placed in the electric field.

Sample Problem

15. An electric field of magnitude 280,000 N/C points due east at a certain spot. What are the magnitude and direction of the force that acts on a charge of −10 μC?

A. 2.8 N to the west
B. 2.8 N to the east
C. 28 N to the west
D. 28 N to the east

Answer

A—To determine the magnitude of the force *(F)* acting on the charge, multiply the magnitude of the electric field *(E)* by the magnitude of the test charge (q_o). Because the charge is negative, it acts opposite to the direction of the electric field. After insertion of the appropriate values in the electric field equation, the magnitude of the charge is determined to be 2.8 N to the west.

$$E = \frac{F}{q_o}$$

Convert the equation to solve for the force *(F)* the test charge will experience:

$$F = Eq_o$$

$$F = (280,000\ \mathrm{N/C})\,(-10\ \mu\mathrm{C})$$

Remember that 1 μC is 1×10^{-6} C.

$$F = (280,000\ \mathrm{N/C})\,(-10\ \mu\mathrm{C})$$

$$F = (280,000\ \mathrm{N/C})\,(-0.00001\ \mathrm{C})$$

$$F = -2.8 \text{ N}$$

The negative sign in the answer indicates the direction of the force relative to the electric field.

$$F = 2.8 \text{ N to the west}$$

Nature and Properties of Circuits

An electric circuit is basically a series of electronic devices or circuit elements connected by a conductive wire that allows electric charges to continuously flow. For there to be continuous flow, there must be a conductive pathway from the positive terminal to the negative terminal and there must be a potential difference between the terminals. The flow of current is determined by the voltage available and the resistance of the circuit. The mathematic relationship between voltage, current, and resistance is known as *Ohm's law,* which states that the potential difference (voltage) in a circuit or any part of that circuit is equal to the current (amperes) multiplied by the resistance (ohms). Ohm's law is expressed as follows, where V = potential difference in voltage expressed in volts, I = current expressed in amperes, and R = resistance expressed in ohms.

$$V = IR$$

Voltage is an expression of the potential difference between two points and is measured in volts. A volt is the work (in joules) that may be done per unit of charge. Current is measured in amperes, which is defined as one coulomb of electricity flowing by a given point in one second. Resistance is measured in ohms and is that property of a circuit element that impedes the flow of electricity. One ohm is equal to the resistance between two points necessary to allow a current of one ampere when one volt is applied.

There are two types of basic circuits: series circuits and parallel circuits. A series circuit has only one pathway through which current can flow, so current is the same through all resistors. A parallel circuit has several pathways through which current can flow, but all resistors are connected directly to the same battery, so the voltage supplied for each resistor is the same. To determine the total resistance of a series circuit, you would add the individual resistors. To determine the total resistance of a parallel circuit, you would add the reciprocal of the individual resistors and then take the reciprocal of that value. Once the total resistance is determined and the type of circuit used is known, the current flowing through each resistor can be determined.

Sample Problem

16. A circuit consists of a 10-ohm resistor, a 15-ohm resistor, and a 25-ohm resistor. The resistors are placed in series and then wired to a 100-V power supply. Determine the current flowing in the circuit.

A. 0.5 amp
B. 2.0 amp
C. 10.0 amp
D. 4.0 amp

Answer

B—Before the current flowing through the circuit can be determined, the total resistance must be calculated. Because the resistors are placed in a series, the total resistance is determined by adding the values of the individual resistors.

$$\text{Total Resistance}_{(\text{in a series})} = \text{R1} + \text{R2} + \text{R3}$$

$$\text{Total Resistance}_{(\text{in a series})} = 10 \text{ ohm} + 15 \text{ ohm} + 25 \text{ ohm}$$

$$\text{Total Resistance}_{(\text{in a series})} = 50 \text{ ohm}$$

To determine the current in the circuit, use the Ohm's law equation. After insertion of the appropriate values into the equation, the current flowing in the circuit is determined to be 2.0 amp.

$$\text{V} = \text{IR}$$

Convert the equation to solve for current *(I)*.

$$\text{I} = \frac{100 \text{ Volts}}{50 \text{ ohms}}$$

$$\text{I} = 2.0 \text{ amps}$$

Magnetism and Electricity

Magnetism is that property of a material that will attract iron, cobalt, or nickel. Magnetic fields exist as lines of force in space known as *flux.* These flux lines create elliptical loops in space that extend from the north pole externally to the south pole of the magnet. As with electric charges, like magnetic poles repel each other and opposite magnetic poles attract. Additionally, the force of attraction or repulsion between two magnetic fields varies directly as the strength of the magnetic poles and inversely as the square of the distance between them. The strength of a magnetic field is measured in Teslas.

Electricity and magnetism are two parts of the same basic force known as electromagnetism. That is, any flow of electricity, whether in space or in a conductor, will create around it an associated magnetic field. Likewise, any moving magnetic field will create an electric current. This induction of an electric current is known as *electromagnetic induction.* When a conductor is passed back and forth in a magnetic field or the flux from a moving magnetic field passes through a conductor, an electric current will be induced to flow in that conductor. Figure 8-9 demonstrates a conductor being rotated in a magnetic field that induces current in the loop to power the light bulb.

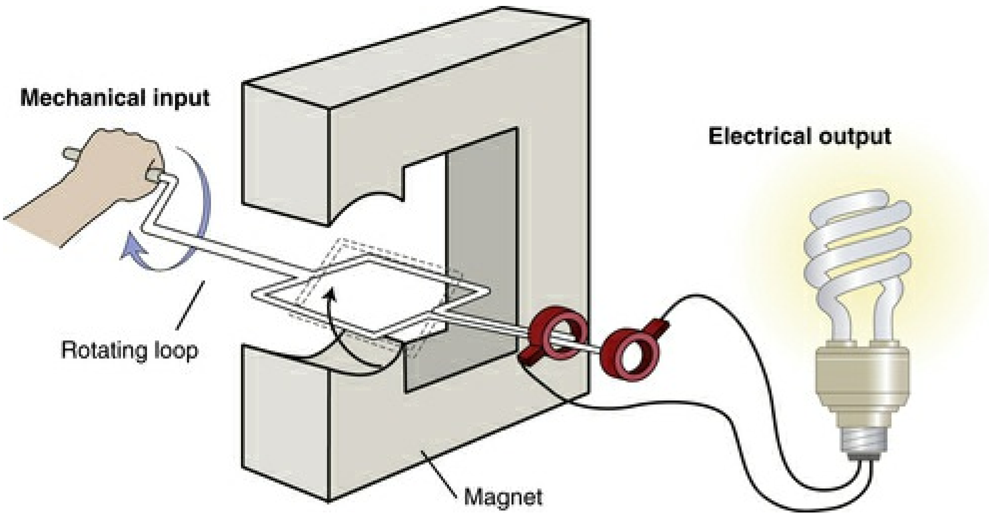

FIGURE 8-9 A conductor rotated in a magnetic field will generate electricity. (From Johnston JN, Fauber TL: *Essentials of radiographic physics and imaging,* ed. 2 St. Louis, 2016, Elsevier Mosby.)

HESI Hint

Magnetism and electricity are fundamental to x-ray production. There is no magical process involved in the production of x-rays by medical imaging equipment. It is simply the manipulation of electricity.

Posttest

1. What is the best definition of the word *comprehensive*?
   A. Complete
   B. Incomplete
   C. Concise
   D. Exclusive
2. Which of the following sentences is grammatically correct?
   A. The patient and the nurse knew that he could walk.
   B. While the patient was walking.
   C. The patient, the nurse and the doctor were walking.
   D. Because the patient could walk, he was allowed to leave his room.
3. Which of the following proteins catalyzes different reactions or processes?
   A. Keratin
   B. Hormone
   C. Enzyme
   D. Collagen

Change fraction to decimal:

4. $^5/_{11}$ = ______________
   A. 0.45
   B. 0.50
   C. 0.25
   D. 0.75
5. $^3/_8$ = ___________________
   A. 0.38
   B. 2.66
   C. 0.006
   D. 1.402
6. Which word in the following sentence is a conjunction?
   The little girl wanted a cookie, but she didn't take one.
   A. Little
   B. But
   C. Take
   D. The
7. A die is rolled once. What is the probability of getting an even number?
   A. 50%
   B. 20%
   C. 33%
   D. 75%
8. Select the meaning of the underlined word in the sentence.
   The nurse called the doctor when the patient's condition began to <u>deteriorate</u>.
   A. Grow
   B. Improve

C. Worsen
D. Clarify

9. As a light wave enters a slower medium, what happens in terms of refraction related to normal?
A. No change with regard to refraction.
B. It will refract away from normal.
C. It will refract toward normal.
D. Light will not pass into a slower medium.

10. Which word in the following sentence is an indirect object?
The doctor gave the patient a prescription.
A. Doctor
B. Prescription
C. Gave
D. Patient

11. One unit of lumber is 3.7 inches wide and another is 1.6 inches wide. How many inches wider is the first unit of lumber than the second?
A. 5.3
B. 5.9
C. 2.3
D. 2.1

12. Which of the following sentences is grammatically correct?
A. The child's torn shirt was lying on the floor.
B. The torn child's shirt was lying on the floor.
C. The child's shirt was lying on the floor torn.
D. The child's shirt torn was lying on the floor.

13. What is the probability that a recessive trait would be expressed in offspring if two parents who are both heterozygous for the desired trait were crossed?
A. 100%
B. 75%
C. 50%
D. 25%

14. Select the word in the following sentence that means "brief, to the point."
The teacher's instructions were concise, so the student was able to complete the project in a reasonable period of time.
A. Period
B. Concise
C. Complete
D. Reasonable

15. In a science class, there are 3 girls and 5 boys. The teacher asks a student to volunteer to come to the board. What is the probability that the student is a girl?
A. ½
B. ⅗
C. ⅜
D. ⅛

16. What word is best to substitute for the underlined words in the following sentence?

The boy watched the lights in the house go off.

A. Him
B. His
C. They
D. He

17. An archer exerts a force of 15 N to pull back the bowstring 15 cm as she prepares to shoot an arrow. How much kinetic energy will be imparted to the arrow as a result of the work done?

A. 225 J
B. 112.5 J
C. 2.25 J
D. 1.125 J

18. How do phospholipids function in cells?

A. They are integral components of the nuclear membrane.
B. They are integral components of the cytoplasmic skeleton.
C. They are integral components of the mitochondrial membranes.
D. They are integral components of the plasma membrane.

19. What word meaning "control" best fits in the sentence?

Discipline decisions were under the __________ of the school principal.

A. Aegis
B. Assent
C. Etiology
D. Access

20. Which of the following describes carbohydrates?

A. They serve as fuel for the body.
B. They are present in DNA but not in RNA.
C. They are the least abundant biomolecule.
D. They cannot be stored in the body.

21. Which of the biologic molecules are considered the most significant contributors to cellular function?

A. Carbohydrates
B. Lipids
C. Proteins
D. Nucleic acids

22. Which word or phrase in the following sentence is the predicate?

Everyone who attended the concert heard the conductor's announcement.

A. The conductor's announcement
B. Everyone
C. Heard the conductor's announcement
D. Who attended

23. Which statement uses a euphemism?

A. The fireman bravely entered the burning building.
B. The nurse told the family, "I'm sorry; your father has passed away."
C. The orderly was laughing about the patient's vomiting episode.
D. Her husband was overjoyed when she told him she was pregnant.

24. During the process of transcription, a sequence of RNA is generated in

which the RNA base cytosine (C) is inserted complementary to the DNA base guanine (G). Which RNA base is inserted complementary to the DNA base thymine (T)?

A. Adenine
B. Cytosine
C. Quinine
D. Thymine

25. Which of the following describes the atomic mass?

A. Mass of protons and electrons
B. Mass of neutrons and electrons
C. Average mass of that element's isotopes
D. Number of moles in a solution

26. Which of the following epithelial types is correctly matched with its major function?

A. Simple squamous epithelium—secretion or absorption
B. Stratified squamous epithelium—changes shape when stretched
C. Stratified squamous epithelium—diffusion
D. Simple columnar epithelium—secretion or absorption

27. In a cell, reactions take place in a series of steps called:

A. Metabolic pathways
B. Chemical bonding
C. Synthesis
D. Hydrolysis

28. Chemical bonding is the bonding of which of the following?

A. One atom to another atom
B. One mole to another mole
C. A proton to an electron
D. One cation to another cation

29. Nerve tissue is composed of neurons and connective tissue cells that are referred to as which of the following?

A. Osteoblasts
B. Neuroglia
C. Osteocytes
D. Arterioles

30. Beta radiation is the emission of which of the following?

A. Large numbers of helium ions
B. An electron
C. High-energy electromagnetic radiation
D. A product of the decomposition of a proton

31. Two (2) more than three (3) times a number is twenty (20). What is that number?

32. In what area of the body would you expect to find an especially thick stratum corneum?

A. Back of the hand
B. Heel of the foot
C. Abdomen

D. Over the shin

33. Select the meaning of the underlined word in the sentence.

The dog developed bilateral weakness in its hindquarters, so the veterinarian created a wheeled cart to help the dog walk.

A. Present on two sides
B. Available for exercise
C. Affecting the left side
D. Affecting the right side

34. Testicular activity is under the control of which hormone(s)?

A. FSH
B. LH
C. GH
D. Both FSH and LH

35. A bicycle trip of 680 m takes 12.6 seconds. What is the average speed of the bicycle?

A. 53.97 m/sec
B. 8,568 m/sec
C. 0.054 km/min
D. 8.57 m/sec

36. What will one liter of a one-molar solution of any element contain?

A. The atomic mass in grams of that element
B. The atomic number in grams of that element
C. The atomic mass in liters of that element
D. The atomic number in liters of that element

37. A cannon is placed on the edge of a cliff that is 300 m tall. The barrel of the cannon is parallel to the ground below. If a cannonball leaves the barrel in a horizontal direction with a velocity of 115 m/sec, how far out from the base of the cliff will the cannonball land?

A. 450.0 m
B. 630.0 m
C. 900.0 m
D. 7,040.3 m

38. Jeffrey has contracted bulbar poliomyelitis, and it has affected the medulla oblongata. The doctors warned the family that his condition is grave and death may be imminent. What functions of the medulla oblongata have warranted such a dire prognosis?

A. The medulla oblongata contains vital centers that control heart action, blood vessel diameter, and respiration.
B. The medulla oblongata contains neural connections of the reticular-activating system.
C. The medulla oblongata contains the pineal gland, which controls the vital centers.
D. The medulla oblongata contains the corpora quadrigemina, which controls the neural transmission of impulses along the spinal cord.

39. Write the following phrase as an expression.

The product of X and 12

A. x +12
B. _12x
C. $x - 12$
D. 12x
40. A car that weighs 15,000 N is initially moving at 60 km/hr when the brakes are applied.
The car is brought to a stop in 30 m. Assuming the force applied by the brakes is constant, determine the magnitude of the braking force.
A. 7,086.7 N
B. 900,000 N
C. 1,500,000 N
D. 30,000 N
41. Which hormone initiates the preparation of the endometrium of the uterus for pregnancy?
A. FSH
B. Estrogen
C. LH
D. Progesterone
42. What is the weakest of all the intermolecular forces?
A. Dispersion
B. Dipole interactions
C. Hydrogen bonding
D. Covalent bonding
43. Select the meaning of the underlined word in the sentence.
The instructions for the <u>otic</u> medication stated "Instill 3 drops daily."
A. Oral
B. Sublingual
C. Transdermal
D. Aural
44. Pairs of magnets are placed in proximity to each other as below. Which pair will experience the greatest force of attraction?
A. 0.5 T (north end) 1 meter from 0.5 T (north end)
B. 2.5 T (south end) 1 meter from 0.5 T (south end)
C. 2.5 T (south end) 1 meter from 0.5 T (north end)
D. 2.5 T (north end) 1 meter from 2.5 T (south end)
Use the passage below to answer questions 45-50.

Allergic Rhinitis

Achoo! For people with allergic rhinitis, this sound is quite familiar. Sneezing is one of the many symptoms experienced by those with allergic rhinitis; other symptoms include runny nose, nasal congestion, postnasal drip, coughing, and itchy eyes, ears, nose, and throat. These symptoms can be irritating, but those who suffer from allergic rhinitis do have several treatment options.

Allergies are caused by an altered immune response. When a person's immune response is functioning properly, the immune system attacks foreign molecules, or antigens, that enter the body. When a person's immune response is altered, however, the immune system attacks substances that are not normally harmful to the body, such as peanuts (in the case of allergies) or the body's own tissue (in the case of an autoimmune disease). Allergic rhinitis, specifically, is caused when a person breathes in particles in the air that the immune system attacks, such as mold, pollen, dust mites, and animal dander. After exposure to these allergens, the body releases a chemical called histamine; this chemical causes many of the symptoms experienced by those with allergic rhinitis.

Allergic rhinitis can be treated in several ways. One option is avoidance of the allergen, such as not having pets, staying indoors on days with a high pollen count, using allergen-protective mattress and pillow covers, and wearing a mask while cleaning. This option can be unrealistic, so often medication is used to treat allergic rhinitis. Medications used include antihistamines, corticosteroids, and decongestants. Both antihistamines and corticosteroids are available in several forms, including oral, injection, nasal spray, and eye drops; decongestants are available as nasal sprays or oral medication. A third option to treat allergic rhinitis is immunotherapy. Through immunotherapy, the person is given a small amount of the allergen, either by injection or a sublingual (under the tongue) tablet. The goal of immunotherapy is for the person's immune system to develop a tolerance for the allergen and, therefore, no longer produce an immune response to it. Immunotherapy is typically given for 3 to 5 years.

45. What is the main idea of the passage?
   A. Allergic rhinitis cannot be treated.
   B. Allergic rhinitis is caused by an altered immune response.
   C. Allergic rhinitis has a lot of irritating symptoms.
   D. Allergic rhinitis symptoms are irritating, but treatment options are available.
46. Which statement is not listed as a detail in the passage?
   A. Histamine is a chemical that causes allergic rhinitis symptoms.
   B. Allergic rhinitis is caused by food allergens such as peanuts.
   C. Allergic rhinitis can be treated with immunotherapy.
   D. Sneezing, runny nose, and coughing are symptoms of allergic rhinitis.
47. What is the meaning of the word *allergens* in the second paragraph?

A. Substances that cause an allergic reaction
B. Foreign molecules
C. Medications that treat allergic rhinitis
D. Chemicals released by the immune system

48. What is the writer's primary purpose in writing this essay?
A. To inform the reader of the cause of allergic rhinitis and how to treat it
B. To entertain the reader with a funny story about allergic rhinitis
C. To persuade the reader that immunotherapy is the best treatment for allergic rhinitis
D. To inform the reader about the body's immune responses

49. What are the three treatment options for allergic rhinitis described in the passage?
A. Antihistamines, decongestants, and corticosteroids
B. Nasal spray, injection, and eye drops
C. Antigens, histamine, and medication
D. Avoidance, medication, and immunotherapy

50. Which of the following statements is an opinion?
A. Allergies are the result of an altered immune response.
B. Immunotherapy is given for 3 to 5 years.
C. Allergic rhinitis symptoms are irritating.
D. Pollen and dust mites can cause allergic rhinitis.

Answers to Posttest

1. A
2. D—D is the only sentence that is grammatically correct. A includes a vague pronoun reference (does *he* refer to the patient or to the nurse?). B is a sentence fragment. C includes a series, and there should be a comma after *nurse.*
3. C
4. A
5. A
6. B
7. A
8. C
9. C
10. D—The indirect object is the person or thing indirectly affected by the action of the verb. In this sentence, *patient* is the indirect object. Indirect objects come between the verb and the direct object.
11. D
12. A—*Torn* is modifying *shirt*, so it should be placed next to shirt. In B, C, and D, the modifier is misplaced.
13. D
14. B
15. C
16. D
17. C
18. D
19. A
20. A
21. C
22. C
23. B
24. A
25. C
26. D
27. A
28. A
29. B
30. B
31. 6
32. B
33. A
34. D
35. A
36. A
37. C
38. A

39. D
40. A
41. B
42. A
43. D
44. D
45. D
46. B
47. A
48. A
49. D
50. C

Glossary

A

Abstract noun The name of a quality or a general idea (e.g., persistence, democracy).

Acceleration The rate of change in velocity over a period of time.

Acid A compound that is a hydrogen or proton donor. It is corrosive to metals, changes blue litmus paper red, and becomes less acidic when mixed with bases.

Adjective A word, phrase, or clause that modifies a noun (the *biology* book) or pronoun (He is *nice*.).

Adverb A word, phrase, or clause that modifies a verb, an adjective, or another adverb.

Alimentary canal The digestive tube that consists of the mouth, pharynx, esophagus, stomach, small intestine, large intestine, rectum, and anus.

Alleles Alternate versions of a gene.

Amino acids Organic compounds that contain at least one amino group and a carboxyl group; building blocks of proteins.

Amylase An enzyme in saliva.

Anatomic position The position of the body where the body is erect, the feet are slightly apart, the head is held high, and the palms of the hands are facing forward.

Anterior View facing forward.

Antonym A word that means the opposite of another word.

Appendicular skeleton The part of the skeleton that includes the girdles and the limbs. The upper portion consists of the pectoral or shoulder girdle, the clavicle and scapula, and the upper extremity. The bones of the arm are the humerus, the radius and ulna, the carpals (wrist bones), the metacarpals (bones of the hand), and the phalanges (bones of the fingers). The lower portion of the appendicular skeleton is made up of the pelvic girdle or os

coxae. Each of the os coxae consists of a fused ilium, ischium, and pubis. Bones of the lower extremity include the femur (thighbone), the tibia and fibula, the tarsals (ankle bones), the metatarsals (bones of the foot), and the phalanges.

Arterioles The smallest type of arteries.

Atom The basic building block of a molecule, which contains a nucleus and orbits.

Atomic mass The *average* mass of each of an element's isotopes.

Atomic number The number of protons in the nucleus, and it defines an atom of a particular element.

Average speed The distance an object travels divided by the time the object travels without regard to direction of travel.

Axial skeleton The 28 bones of the skull. These are separated into the 14 facial bones and the 14 bones of the cranium.

B

Base A hydrogen or proton acceptor and generally has a hydroxide (OH) group in the makeup of the molecule. Bases are also called *alkaline compounds* and are substances that denature proteins, making them feel very slick; they change red litmus paper blue and become less basic when mixed with acids.

Basic unit of measure Standard unit of a system by which a quantity is accounted for and expressed (grams, liters, or meters).

Binary fission Type of asexual reproduction; parent cell splits into two identical daughter cells.

Binding energy How tightly the electron is bound to the nucleus.

Biochemistry The study of chemical processes in living organisms.

Bolus A ball of food that is formed after the food is broken down by the teeth and saliva.

C

Catalysts Substances that accelerate a reaction by reducing the activation energy or the amount of energy necessary for a reaction to occur.

Cell The basic unit of life and the building block of tissues and organs.

Celsius A temperature system used in most of the world and by the scientific

community; abbreviated C. It has these characteristics: zero degrees (0° C) is the freezing point of pure water at sea level, and 100° C is the boiling point of pure water at sea level. Most people have a body temperature of 37° C.

Centripetal acceleration Rotational motion equivalent of acceleration.

Cerebellum A part of the brain responsible for muscular coordination.

Cerebrum The part of the brain associated with movement and sensory input.

Chemical equations Combination of elements or compounds called reactants responding to create a product or end result. Equations are written in the following manner: Reactants → Products. (In some instances the arrow can go the other way or both ways.)

Chromosomes Compact, rod-shaped bodies located within the nucleus of a cell; contain DNA.

Chyme The soupy substance that is created by the stomach churning and mixing the bolus food mass.

Clause A group of words that has a subject and a predicate.

Cliché An expression or idea that has lost its originality or impact over time because of excessive use.

Codon Three-base sequence of messenger RNA.

Collective noun A collective noun is a noun that represents a group of persons, animals, or things (e.g., family, flock, furniture).

Combustion A self-sustaining exothermic chemical reaction usually initiated by heat acting on oxygen and a fuel compound such as hydrocarbons.

Common denominator Two or more fractions having the same denominator.

Common noun A common noun is the general, not the particular, name of a person, place, or thing (e.g., nurse, hospital, syringe).

Compound The combination of two or more elements or atoms.

Compound sentence A sentence that has two or more independent clauses. Each independent clause has a subject and a predicate and can stand alone as a sentence.

Conjunction A word that joins words, phrases, or clauses.

Connotation The emotions or feelings that the reader attaches to words.

Constant A number that cannot change.

Context clue The information provided in the words or sentences surrounding

an unknown word or words.

Covalent bond Two atoms share electrons, generally in pairs, one from each atom.

D

Declarative A declarative sentence makes a statement.

Decomposition A chemical reaction often described as the opposite of synthesis because it is the breaking of a compound into its component parts.

Denominator The bottom number in a fraction.

Deoxyribonucleic acid (DNA) A unique molecule specific to a particular organism; it contains the genetic code that is necessary for replication.

Deoxyribose A sugar used in the formation of DNA.

Dependent clause A dependent clause begins with a subordinating conjunction and does not express a complete thought and therefore cannot stand alone as a sentence.

Dermis The layer of skin that consists of the underlying layer of connective tissue with blood vessels, nerve endings, and the associated skin structures.

Digit Any number from 1 through 9 and 0 (e.g., the number 7 is a digit).

Direct Object The person or thing that is directly affected by the action of the verb.

Distal Term of direction usually used in reference to limbs. Distal means farther away from the point of attachment.

Dividend The number being divided.

Divisor The number by which the dividend is divided.

Double replacement A reaction that involves two ionic compounds. The positive ion from one compound combines with the negative ion of the other compound. The result is two new ionic compounds that have "switched partners."

E

Electron A structure in an atom that is at the outermost part of the atom and has a negative charge. Electrons orbit the nucleus at fantastic speeds, forming electron clouds.

Electron clouds The group of electrons revolving around the nucleus of an atom; a cloudlike group of electrons.

Electron transport chain Series of steps in cellular respiration that produces water and ATP.

Epidermis The layer of skin that consists of the outermost protective layer of dead keratinized epithelial cells.

Equilibrium A state in which reactants are forming products at the same rate that products are forming reactants.

Erythrocytes Red blood cells.

Estrogen Any of several major female sex hormones produced primarily by the ovarian follicles of female mammals, capable of inducing estrus, developing and maintaining secondary female sex characteristics, and preparing the uterus for the reception of a fertilized egg.

Euphemism A mild, indirect, or vague term that has been substituted for one that is considered harsh, blunt, or offensive.

Exclamatory A sentence expressing strong feelings or making an exclamation.

Exponent A number or symbol placed above and after another number or symbol (a superscript or subscript), indicating the number of times to multiply.

Expression A mathematic sentence containing constants and variables (e.g., $3x - 2$).

External respiration The exchange of gases between the atmosphere and the blood through the alveoli.

F

Factor A number that divides evenly into another number.

Fahrenheit A temperature-measuring system used only in the United States, its territories, Belize, and Jamaica; abbreviated F. It is rarely used for any scientific measurements except for body temperature. It has these characteristics: zero degrees (0°) is the freezing point of sea water or heavy brine at sea level; 32° F is the freezing point of pure water at sea level; 212° F is the boiling point of pure water at sea level; most people have a body temperature of 98.6° F.

Force A push or pull on an object.

Fraction bar The line between the numerator and denominator. The bar is

another symbol for division.

Friction A force that opposes motion and is expressed in newtons.

G

Glycolysis Anaerobic breakdown of glucose; first stage in cell respiration.

Golgi apparatus Cell organelle that packages, processes, and distributes molecules about or from the cell.

Groups Elements that are placed together in columns in the periodic table.

H

Hemopoiesis Blood cell formation.

Heterozygous Trait in an organism that contains different alleles.

Histology The study of tissues.

Homozygous Trait in an organism that contains identical alleles.

I

Imperative An imperative sentence makes a command or request.

Impulse equation When both sides of Newton's second law of motion are multiplied by Δt (change in time), a new relationship between force and time is established ($F\Delta t = m\Delta v$) because a force applied over a period of time is an impulse.

Independent clause An independent clause expresses a complete thought and can stand alone as a sentence.

Indirect object The person or thing that is indirectly affected by the action of the verb.

Inference An educated guess or conclusion drawn by the reader based on the available facts and information.

Inferior View from below.

Infundibulum The stalk that attaches the pituitary gland to the hypothalamus.

Interjection A word or phrase that expresses emotion or exclamation.

Internal respiration The exchange of gases between the blood and the body

cells.

Interphase Stage of the cell cycle during which growth and DNA synthesis occur.

Interrogative An interrogative sentence asks a question.

Ionic bond An electrostatic attraction between two oppositely charged ions or a cation and an anion. This type of bond is generally formed between a metal (cation) and a nonmetal (anion).

Isotope Different kinds of the same atom that vary in weight; for a given element, the number of protons remains the same, while the number of neutrons varies to make the different isotopes.

J

Joule A newton-meter or a kilogram-meter squared per second squared (kg-m^2/s^2).

K

Kelvin A unit of measure for temperature that is used only in the scientific community. Kelvin (K) has these characteristics: zero degrees Kelvin (0K) is −273° C and is thought to be the lowest temperature achievable or absolute zero (0); the freezing point of water is 273K; the boiling point of water is 373K; most people have a body temperature of 310K.

Kinetic energy The energy resulting from the motion of the object and is represented by the following equation, where KE = kinetic energy, m = mass of the object, and v = velocity.

Krebs cycle Series of reactions that occur in the mitochondrion during cellular respiration

L

Lateral Away from the midline or toward the sides.

Law of universal gravitation Every object in the universe attracts every other object in the universe.

Least common denominator The smallest multiple that two numbers share.

Leukocytes White blood cells.

M

Mathematic sign. A symbol used in mathematics. A mathematic sign makes up one of the three parts of scientific notation and designates whether the number is positive or negative (+ or −).

Medial View toward the midline.

Medulla oblongata The part of the brain that controls many vital functions such as respiration and heart rate.

Meiosis The special cell division that takes place in the gonads (the ovaries and testes). In the process of meiosis, the chromosome number is reduced from 46 to 23, so when the egg and the sperm unite in fertilization, the zygote will have the correct number of chromosomes.

Meiosis Type of nuclear division that occurs as part of sexual reproduction; each daughter cell receives the haploid number of chromosomes.

Messenger RNA (mRNA) Type of RNA formed from a template of DNA; carries coded information to form proteins.

Metabolic pathway Series of linked chemical reactions.

Metaphase plate Disk formed during metaphase in which the chromosomes align on equatorial plane of the cell.

Misplaced modifiers Words or groups of words that are not located properly in relation to the words they modify.

Mitosis The process in which the DNA is duplicated and distributed evenly to two daughter cells.

Mitosis Type of cell division that produces two identical daughter cells; phases include prophase, prometaphase, metaphase, anaphase, and telophase.

Mole A way to express concentrations of atoms. It is 6.02×10^{23} of particles.

Momentum The amount of motion displayed by an object and is represented by the mathematic equation $p = m\Delta v$, where p = the momentum in kilograms-meters per second, m = the mass in kilograms, and Δv = the change in velocity of the object.

N

Neuroglia Connective tissue cells in nerve tissue.

Neutron Part of the nucleus of an atom that has no charge.

Newton Unit of force.

Noun A word or group of words that names a person, place, thing, or idea.

Nucleus The positively charged mass within an atom, composed of neutrons and protons, and possessing most of the mass but occupying only a small fraction of the volume of the atom.

Numerator The top number in a fraction.

O

Orbit The outermost part of the atom that consists of electrons that spin around the nucleus at fantastic speeds forming electron clouds.

Organelles Any of many cell "organs" or organized components.

Osteoblasts The cells that form compact bone.

P

Participial phrase A phrase that is formed by a participle, its object, and the object's modifiers; the phrase functions as an adjective.

Participle A type of verb form that functions as an adjective.

Percent Per hundred (part per hundred).

Periodic table A table that organizes the elements based on their structure and thus helps predict the properties of each of the elements. It is made up of a series of rows called *periods* and columns called *groups*.

Periods A series of rows within the periodic table that classify the elements.

Personal pronoun A personal pronoun refers to a specific person, place, thing, or idea by indicating the person speaking (first person), the person or people spoken to (second person), or any other person, place, thing, or idea being talked about (third person).

pH The concentrations of acids. The pH scale commonly in use ranges from 0 to 14 and is a measure of the acidity or alkalinity of a solution.

Phagocytosis Process in which cells engulf food particles through the cell membrane.

Phospholipids Phosphate-containing fat molecules; form the bilayer of a cell membrane.

Photosynthesis Chemical process that converts light energy to synthesize carbohydrates.

Phrase A group of two or more words that acts as a single part of speech in a sentence.

Place value The value of the position of a digit in a number (e.g., in the number 659, the number 5 is in the "tens" position).

Platelets An element of blood that is active in the process of blood clotting.

Possessive pronoun A form of personal pronoun that shows possession or ownership.

Posterior View toward the back.

Potential energy The energy the object has because of its position and is expressed by the equation PE = mgh, where PE = potential energy, m = mass of the object, g = acceleration caused by gravity, and h = the height at which the object is located above the ground.

Predicate The part of the sentence that tells what the subject does or what is done to the subject.

Predicate adjective An adjective that follows a linking verb and helps to explain the subject.

Predicate nominative A noun or pronoun that follows a linking verb and helps to explain or rename the subject.

Prefix Each metric measurement is composed of a metric prefix and a basic unit of measure (e.g., "kilogram," where "kilo" is the prefix and "gram" is the basic unit of measure). The prefixes are the same and have the same meaning or value, regardless of which basic unit of measurement (grams, liters, or meters) is used. Prefixes are the quantifiers of the measurement units. All of the prefixes are based on multiples of ten. Any one of the prefixes can be combined with one of the basic units of measurement.

Preposition A word that shows the relationship of a noun or pronoun to some other word in the sentence.

Product The answer to a multiplication problem.

Products Substances or compounds created from a chemical reaction.

Progesterone A hormone secreted by the corpus luteum, which further stimulates development of the endometrium.

Projectile An object that displays two types of motion simultaneously.

Pronoun A word that takes the place of a noun, another pronoun, or a group of words acting as a noun.

Proper noun A proper noun is the official name of a person, place, or thing (e.g., Fred, Paris, Washington University). Proper nouns are capitalized.

Proportion Two ratios that have equal values.

Proton Part of the nucleus of an atom that has a positive electric charge.

Proximal Term of direction usually used in reference to limbs, meaning closer to the point of attachment.

Punnett square Grid used to predict genotype and phenotype of the offspring of sexual reproduction.

Q

Quotient The answer to a division problem.

R

Ratio A relationship between two numbers.

Reactants The part of a chemical reaction that reacts to produce a desired end result or compound.

Reciprocals Pairs of numbers that equal 1 when multiplied together.

Reflection The bouncing back of a wave from a barrier or from a boundary between two media.

Refraction The bending of a wave as it passes at an angle from one medium into another if the speed of propagation differs.

Remainder The portion of the dividend that is not evenly divisible by the divisor.

Ribonucleic acid (RNA) Nucleic acid found in both the nucleus and cytoplasm of the cell; occurs in three forms: mRNA, ribosomal RNA, and tRNA.

Ribose Sugar used in the formation of RNA.

Rough ER Section of the endoplasmic reticulum (ER) that is covered with ribosomes; responsible for protein synthesis and membrane production.

Run-on sentence Two or more complete sentences are written as though they were one sentence.

S

Sarcomeres Small units that make up myofibrils, which make up each muscle cell.

Scalar quantity Quantity described simply by a numeric value.

Scientific notation The scientific system of writing numbers; a method to write very big or very small numbers easily; composed of three parts: a mathematic sign (+ or −), the significand, and the exponential, sometimes called the *logarithm.*

Sentence A group of words that expresses a complete thought.

Sentence fragment Incomplete sentence.

Sexist language Spoken or written styles that do not satisfactorily reflect the presence of women in our society.

Significand The base value of the number or the value of the number when all the values of ten are removed. Used in scientific notation.

Single replacement Reactions that consist of a more active metal reacting with an ionic compound containing a less active metal to produce a new compound.

Smooth ER Section of the endoplasmic reticulum (ER) that lacks ribosomes; functions in detoxification and metabolism of multiple molecules.

Solute The part of a solution that is being dissolved.

Solution A homogeneous mixture of two or more substances.

Solvent The part of the solution that is doing the dissolving.

Steroid Lipid that is a component of a cell membrane; many steroids are precursors to significant hormones.

Stop codon Sequence of bases that terminates translation during protein synthesis.

Subject A word, phrase, or clause that names whom or what the sentence is about.

Superior View from above.

Synergists Muscles that work in cooperation with the prime mover muscle.

Synonym A word that means the same thing as another word.

Synthesis A type of chemical reaction in which two elements combine to form

a product. An example is the formation of potassium chloride (KCl) salt when a solution of potassium (K) combines with chloride (Cl^-).

T

Terminating decimal A decimal that is not continuous.

Textspeak A language that is often used in text messages, emails, and other forms of electronic communication; it consists of abbreviations, slang, emoticons, and acronyms.

Tone The attitude or feelings the author has about the topic.

Transcription Process during protein synthesis in which the DNA molecule is used as a template to form mRNA.

transfer RNA (tRNA) RNA involved in protein synthesis; transfers a specific amino acid to the ribosome and binds it to mRNA.

V

Valence electrons Electrons in the outermost shell that are good conductors of electricity.

Variable A letter representing an unknown quantity (e.g., x).

Vector quantity Quantity describing the time rate of change of an object's position.

Velocity Speed in a specific direction.

Verb A word or phrase that is used to express an action or a state of being.

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